ASTRONOMY

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Light Pollution: A Menace to Astronomy

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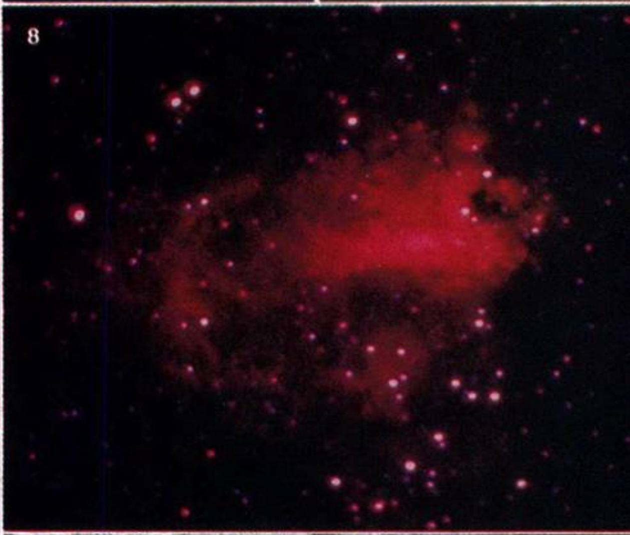
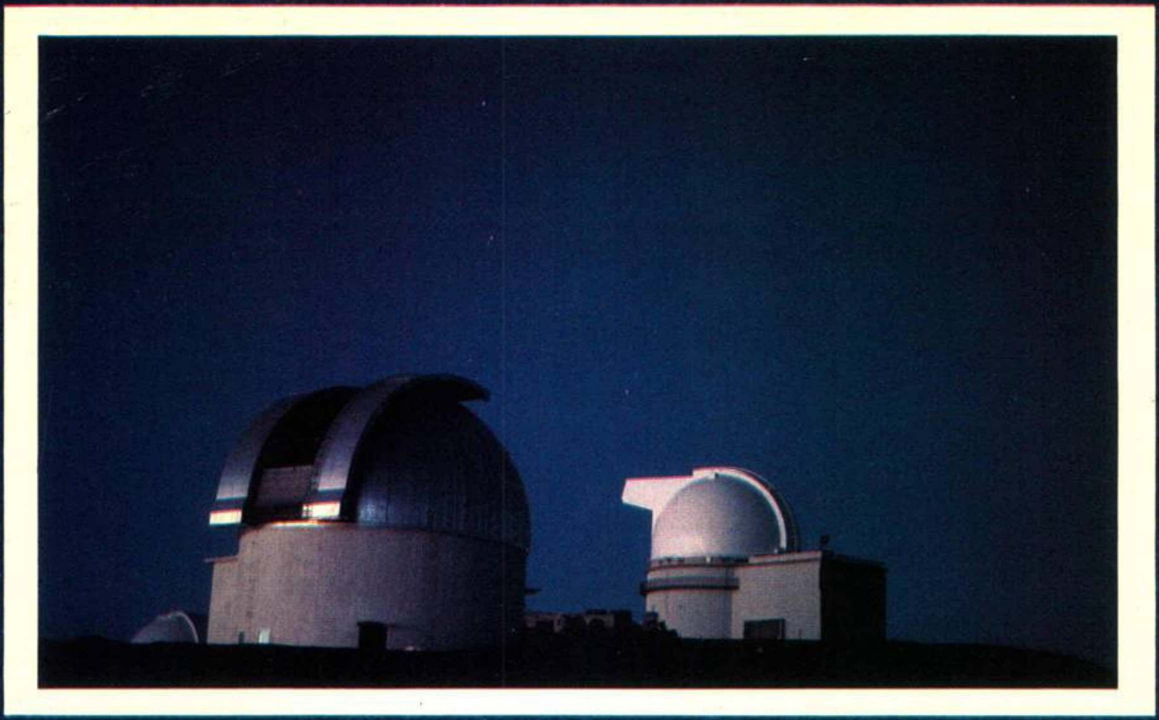
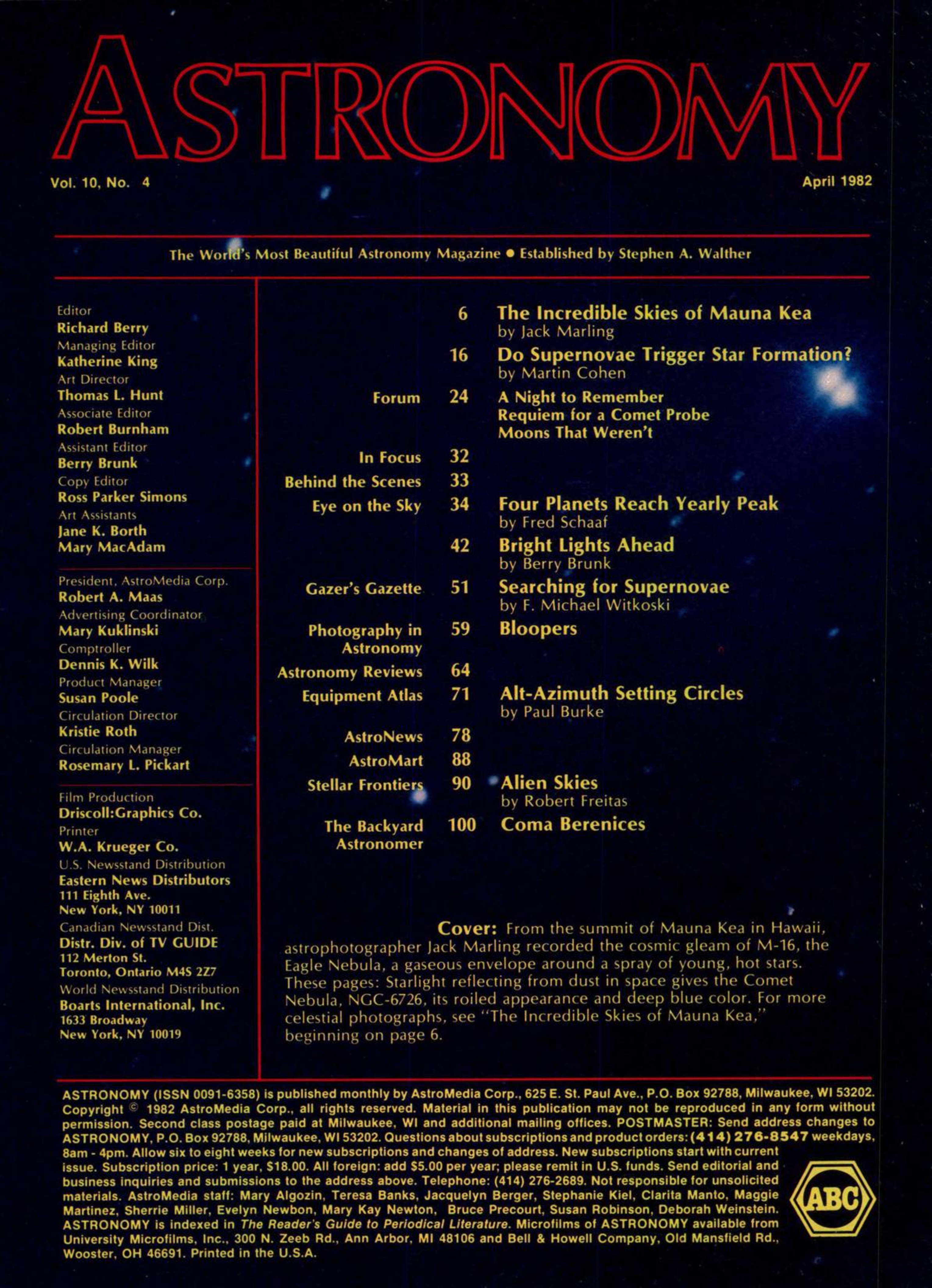


All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5, 7 — Leo Henzl; 4, 6, 8 — Emery Hildebrand;
9 — John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 60 mins. **7.** Galaxy NGC 253; 40 mins. **8.** Omega Nebula M17; 40 mins.; **9.** Moon — Clavius region; 1-sec.





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Cover: From the summit of Mauna Kea in Hawaii, astrophotographer Jack Marling recorded the cosmic gleam of M-16, the Eagle Nebula, a gaseous envelope around a spray of young, hot stars. These pages: Starlight reflecting from dust in space gives the Comet Nebula, NGC-6726, its roiled appearance and deep blue color. For more celestial photographs, see "The Incredible Skies of Mauna Kea," beginning on page 6.

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ABC

M-27, the Dumbbell Nebula

the Incredible Skies of Mauna Kea

by Jack Marling

Omega Centauri

The summit of Mauna Kea on the island of Hawaii ranks as one of the best astronomical sites in the world. I know, because I was there.

Not every amateur astronomer gets to spend a week under some of the best skies on Earth, above much of Earth's atmosphere, with time on a pretty large telescope. But I was lucky. By applying well in advance to the director of the Institute for Astronomy at the University of Hawaii with a suitable project, I found myself scheduled for a week of observing with a 24-inch telescope!

Mauna Kea is one of the two giant volcanic mountains that make up the bulk of the big island Hawaii. The other volcano, Mauna Loa, still erupts from time to time, but Mauna Kea is no longer active. So the summit of Mauna Kea has become the home of many large international telescopes. Its fantastic seeing, low latitude, dry air, and 13,800-foot elevation help explain its popularity with astronomers.

All astronomers observing on Mauna Kea stay at Hale Pohaku — the Half-Way House — located high on the flank of Mauna Kea, about 4600 feet lower than the summit. This elevation provides a more comfortable altitude for sleeping, study, and living. Acclimatization to life 2½ miles up is difficult for some people, and can cause headaches and other forms of altitude sickness. But it usually takes only about 24 hours to adjust to it, so the observatory requires all astronomers to spend one day at Hale Pohaku before using telescopes on the summit.

Staying at Hale Pohaku provided another benefit — I met other Mauna Kea astronomers. The man using the 88-inch University of Hawaii telescope, Alan Stockton, was photographing faint galaxies and quasars looking for evidence of quasars in clusters of galaxies. Dr. Rene Racine, director of the CFH telescope, was pleased to see someone taking color photographs. He wants to use the great light-gathering power and superb resolution of the 3.6-meter reflector to show the people of Hawaii, through photographs of the heavens, what the astronomers are doing up on the mountain.

Since the road from Hale Pohaku to the summit is extremely rugged, I was lucky to catch a ride with some other astronomers each night. Perhaps you think of Hawaii as warm, but on the mountain, you must be prepared for thin, icy air — and once you're up there, there's no going down until morning. I dressed very warmly — in several thick wool sweaters and a hat, a down parka, and heavy gloves.

After acclimatizing, I was ready to work. My goal was to test several forming gas hypersensitized films for color deep-sky photography. The telescope I was to use, the Air Force 24-inch f/15 Cassegrain, has an effective focal length of 9100mm, providing an image scale much too generous. Even a 32mm Erfle eyepiece gave me 300x! So, since I planned to use only 35mm film, I brought an 82mm diameter f/4 achromat lens, and installed it 12 centimeters in front of the 35mm camera. This brought the light to a shorter focus, giving the telescope an effective focal ratio of f/6.5, much better suited to color photography than f/15. It also doubled the angular field of view and reduced the exposure time about five-fold. Unfortunately the lens also introduced some curvature of field, so the edges of the pictures I took were a bit out of focus.

Mauna Kea's World-Class Skies

Mauna Kea, Hawaii, is rapidly becoming a world center for astronomy. It is superb for visual astronomy, since its skies are clear more than 75% of the nights throughout the year. The seeing is often 1 arc-second, but it can occasionally reach a superb 0.2 arc-second.

Mauna Kea is also uniquely suited for infrared astronomy, since its 13,800-foot elevation places it above 90% to 99% of atmospheric water vapor, the primary absorber of infrared light.

Four of the world's largest telescopes keep a vigil on the night sky at the summit of Mauna Kea. The first installed was the University of Hawaii's 2.2-meter telescope, now the smallest of the four main telescopes. The Canada-France-Hawaii (CFHT) 3.6-meter telescope in its unique hyper-hemispherical dome, NASA's 3-meter infrared telescope facility (IRTF), and the United Kingdom 3.8-meter infrared telescope (UKIRT) now share the mountain, too.

Besides the telescopes already in operation, there are plans to locate the University of California's proposed 10-meter multiple mirror telescope on Mauna Kea. Astronomers are now evaluating various sites on the summit.

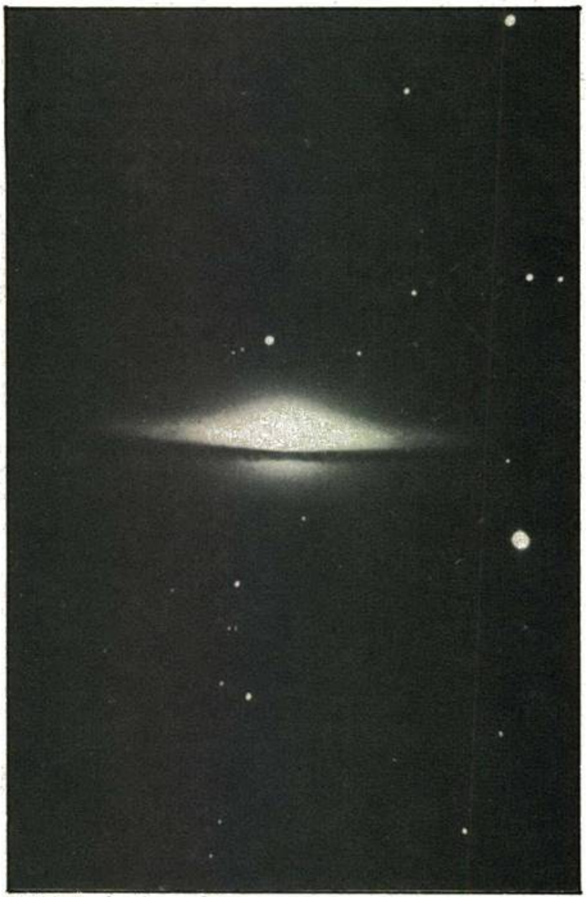
Two more "small" telescopes are also located on Mauna Kea: the Air Force 24-inch and the International Planetary Patrol 24-inch. The Air Force telescope is currently used very little, and amateur astronomers are sometimes allowed to use it for observing projects.

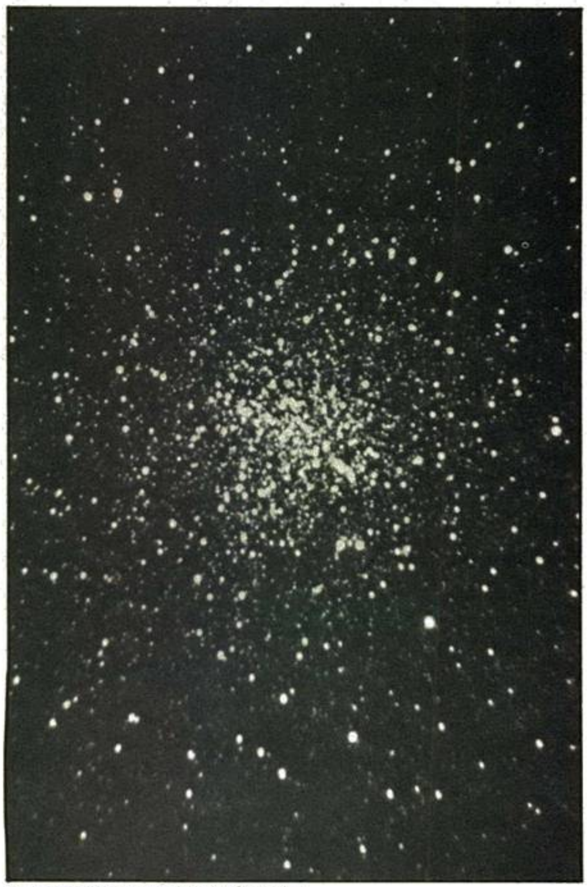
Although my primary goal was a test of color films, I carefully left myself enough extra time to visually enjoy and appreciate what I was photographing. In some cases, objects I had not even planned to photograph — like the Eye Nebula — were so visually striking that I could not resist photographing them, too.

The 24-inch telescope is controlled with a "paddle" attached to the control panel by a long cable. At the beginning of each night's observing, I set the right-ascension dial by pointing the telescope to a bright star whose coordinates I knew. I found sky objects by moving the telescope in right ascension and declination according to two large luminous dials on the control panel located in the base of the telescope mount.

Its low latitude — just 20° north of the equator — gives Mauna Kea access to nearly all of the celestial sphere. But the 24-inch telescope was limited to objects above -50° declination, so I observed more southerly targets with an 8-inch f/10 Cassegrain lent to me by an amateur astronomer living in the nearby town of Kamuela.

Surely, the nearest neighbor to the Sun, Alpha Centauri, holds a special attraction for every astronomer because it is a mere 4.3 light-years away. Without a doubt, it is also the most spectacular double star in the sky. Both first magnitude components — separated by 20 seconds of arc — were brilliant even though they rose only about 10° above the southern horizon. They share a beautiful golden hue in the 8-inch, and I could not help but wonder about what planets might circle these stars.


M-104, the Sombrero Galaxy


M-4, a globular cluster in Scorpius

I was hardly prepared for Omega Centauri — what a magnificent globular cluster! At 300x it completely overflowed the field in a continuous sea of thousands of stars. And it was so visually bright that the pictures I took just begin to give a feeling for it. Omega Centauri is one example where direct viewing with a telescope is far more splendid than any photograph.

The famous Sombrero Galaxy was a lovely sight. It is tilted only 6° from edge-on, and I could easily see its dark lane of dust surrounded by luminosity on both sides. I photographed it on hypered 2415 film.

Another bright globular cluster, M-4, lies conveniently near Antares in Scorpius. Although it is nowhere near Omega Centauri in brightness, it has a distinct visual feature — a band of stars across its center. You can see this in any small aperture telescope, but it was a stunning sight with a big telescope high on Mauna Kea.

Ironically, while I went to Hawaii to escape light pollution, I still found it atop Mauna Kea — but it was light pollution of a different kind. All the long-exposure photographs show it — the bluish haze due to the scattered light of thousands of stars. I was in Hawaii just a month after the eruption of Mt. St. Helens, and there might have been more dust in the stratosphere than usual.

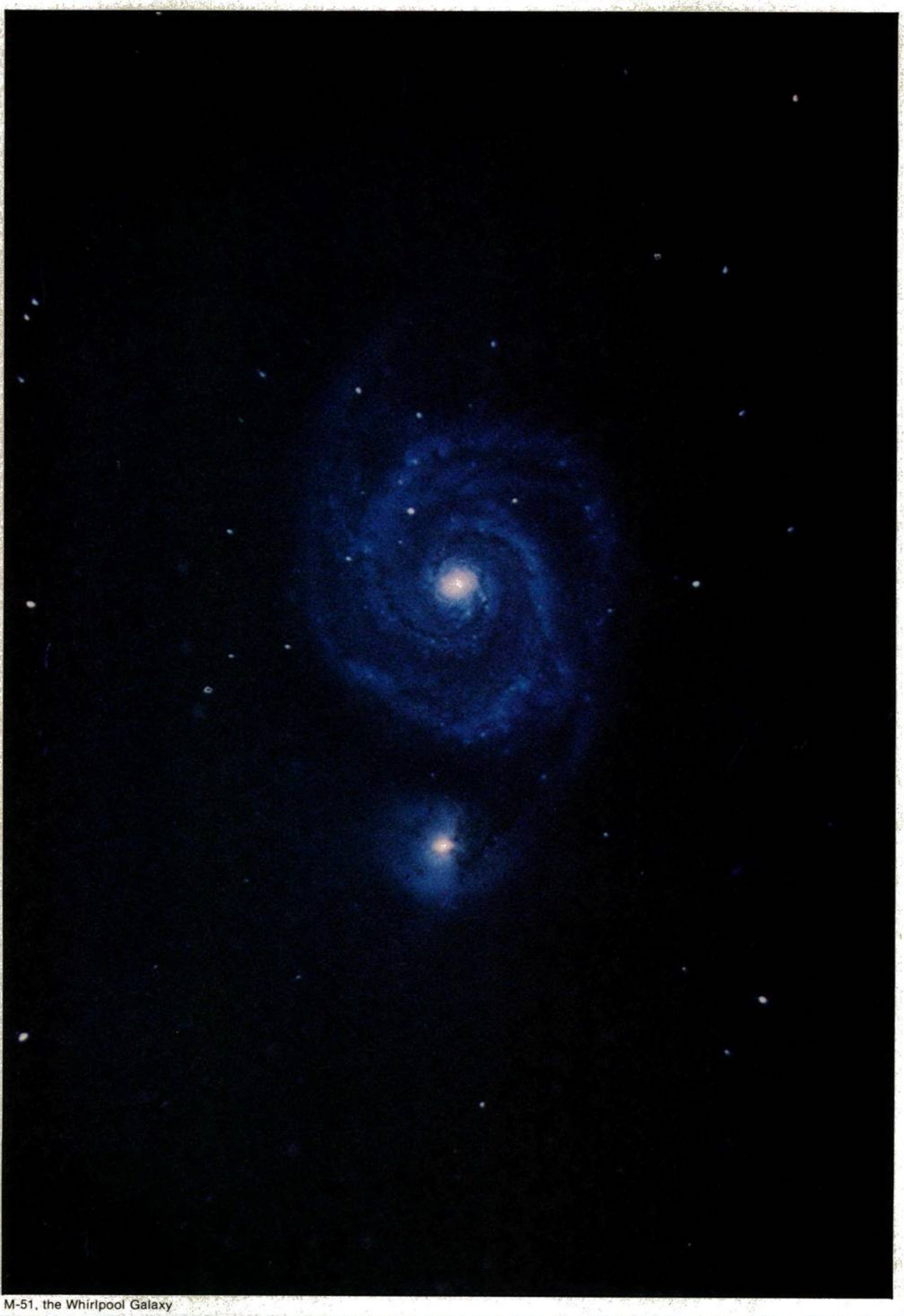
To northern hemisphere observers, the great Whirlpool Galaxy in Canes Venatici is a familiar sight. Visually it is very lovely; its spiral arms show distinctly in the 24-inch telescope. I took two pictures — one on black-and-white 2415 film, a 40-minute exposure somewhat hindered by cirrus clouds, and the one shown here, a 30-minute exposure on Fujichrome RD100.

I had never before seen the central star in the Ring Nebula — yet under the fine skies and 0.8 arc-second seeing on the mountain, I wondered if I would now see it. It was not visible at 200x, but at 500x, I could see it clearly with averted vision, as it popped in and out of view. I doubt that many people can actually see the central star in any telescope under 20-inch aperture. Even from Mauna Kea with a 24-inch in good seeing conditions, it was difficult. But the central star shows clearly in the photographs.

Another fascinating object was an 11th magnitude planetary nebula in Scorpius. Its very unusual elongated shape and a bright central star have earned it the title of The Bug Nebula. I saw no color through the telescope, but the Bug glows red in the pictures.

On the night I photographed the Eye Nebula, Bill Heacox — the man responsible for scheduling observations — joined me. He said that most astronomers don't look at what they're observing. I offered to show him the Eye — and he was delighted with it. This nebula is exceedingly bright — bright enough to slightly excite color vision and display a definite blue color. Because of its small size and great brightness, I removed the focal reducing lens and photographed it at f/15.

Any astronomer worth his salt wants a look at the Orion Nebula with a big telescope. I had my view of M-42 at 300x — *too much* magnification to see the whole nebula. The innermost core looks turbulent and chaotic, with lots of mottling, while the stars of



M-51, the Whirlpool Galaxy

M-57, the Ring Nebula

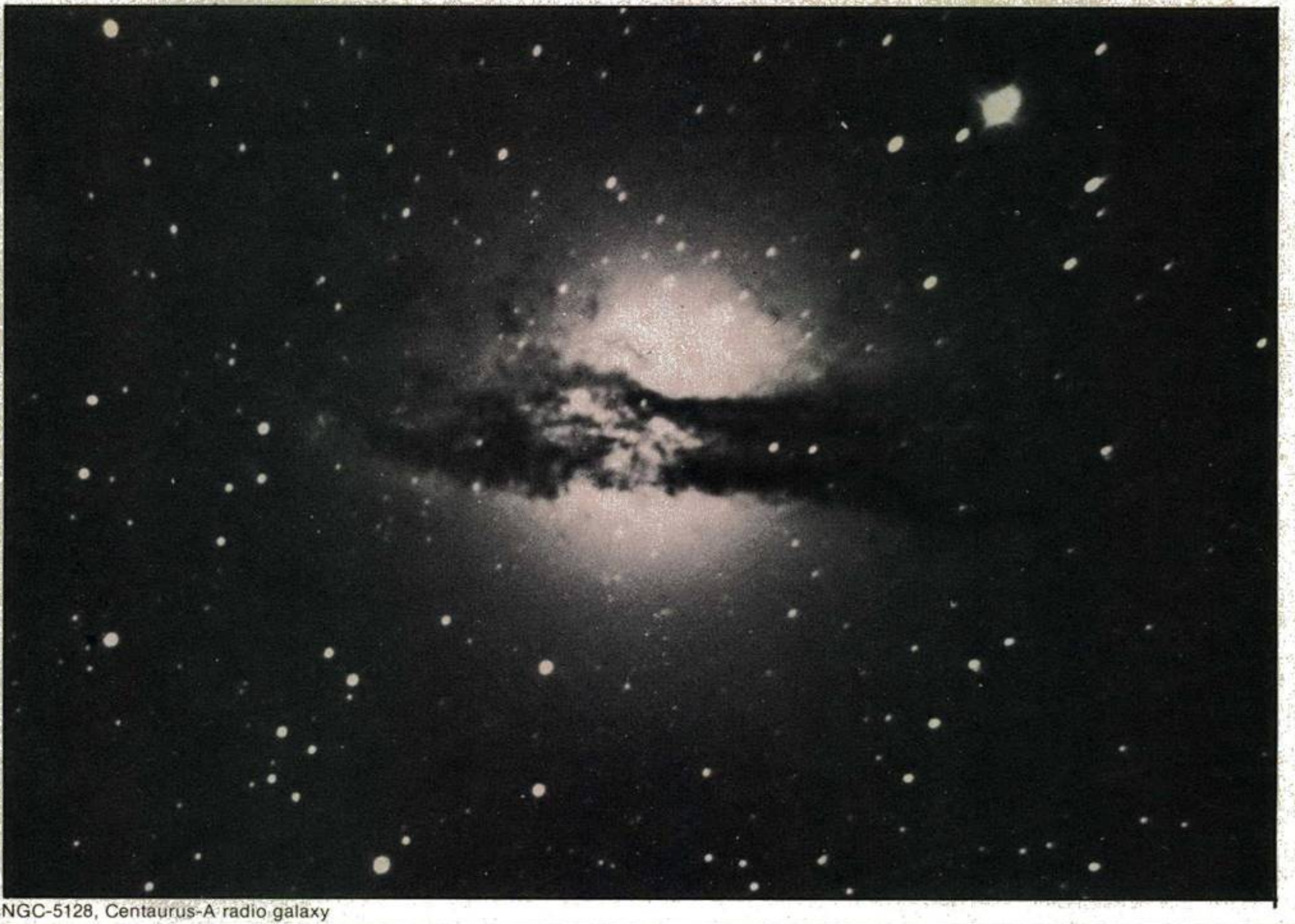
NGC-6302, the Bug Nebula

NGC-3242, the Eye Nebula

M-42, the Great Nebula in Orion

M-17, the Swan Nebula

M-11, the Wild Duck Cluster



NGC-5128, Centaurus-A radio galaxy

the Trapezium shone a brilliant blue-white. I could see six components of this famous multiple star — and I made a 30-second exposure to record the sight.

Near the Serpens-Sagittarius border is a stunning nebula, M-17. Its distinct shape has inspired many nicknames — the Swan, Omega, Checkmark, or Horseshoe Nebula. It's a place where new-born stars buried within a cloud of interstellar material cause gas to glow. To the eye it appears a greyish tone, essentially colorless. But again the color film recorded what my eyes could not — its deep ruddy glow.

The Wild Duck cluster, M-11, is one of the loveliest open clusters in the sky. From Hawaii, I saw it nearly straight overhead. At 300x, it filled the entire field with stars — a far cry from the comet-like glow that Messier saw.

Because it never rises very high, most northern hemisphere observers aren't really familiar with Centaurus-A, the great weird radio galaxy. NGC-5128 is one of the most peculiar galaxies known. It seems to have ejected material with explosive violence, and we now see stars forming within it at a prodigious rate. Visually, it has a dark, irregular band across the middle. As I looked into the eyepiece, I wondered what forces drive its distant violence.

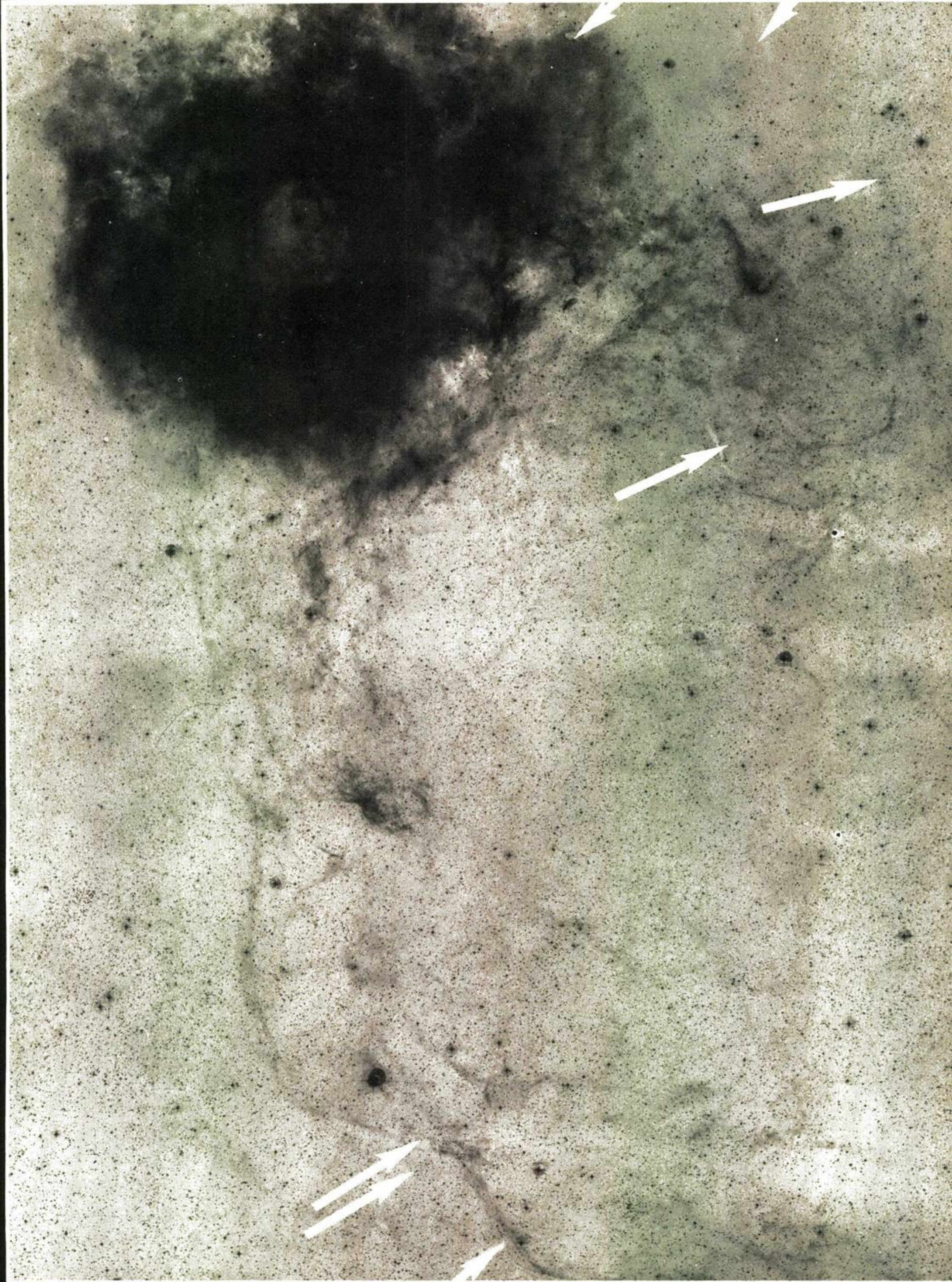
Although the high altitude and far-below-freezing cold present a hindrance, observing under Mauna Kea's crystal skies is a truly delightful astronomical experience. The amazing views of Omega Centauri, the Eye Nebula and other deep-sky splendors will always be with me.

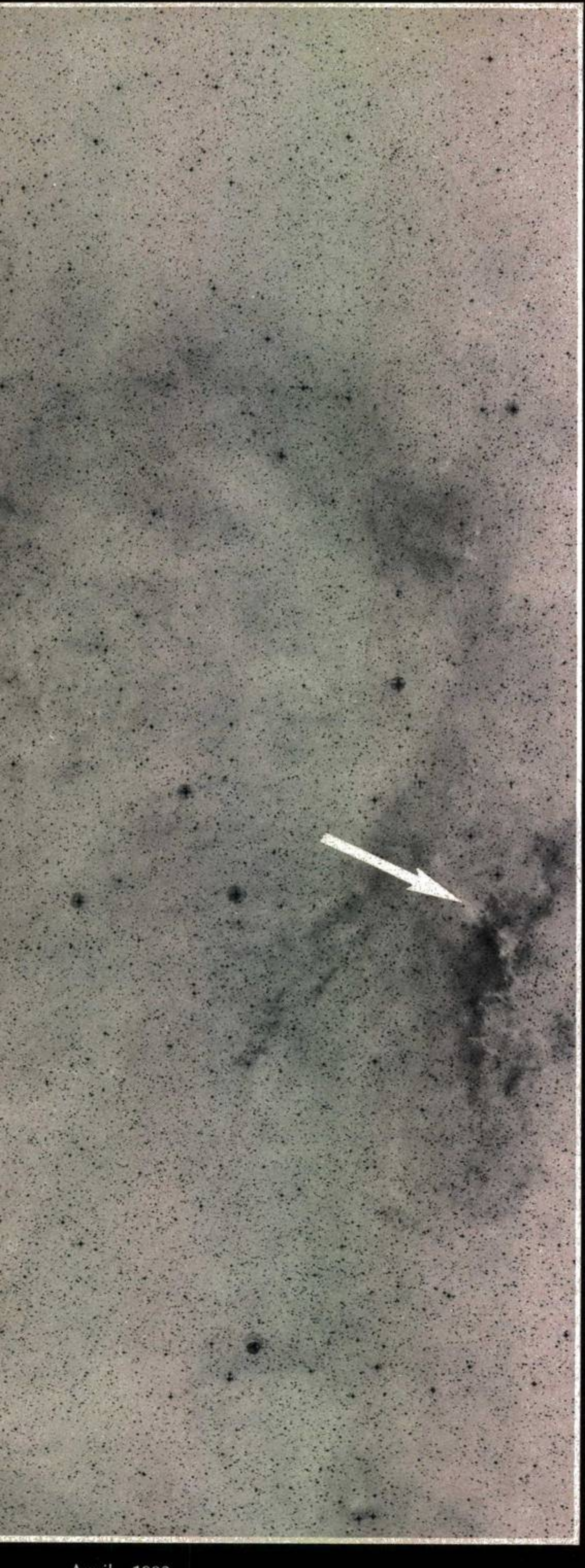
Photo Data

Page	Object	Name	Exposure	Film
Cover	M-16	Eagle N.	30 min	RD100-N
4-5	NGC-6726	Comet N.	15 min	K-400
6	M-27	Dumbbell N.	30 min	RD100-N
8	NGC-5139	Omega Cen.	7 min	RD100-N
10, t	M-104	Sombrero G.	30 min	2415-H
10, b	M-4	—	15 min	2415-H
11	M-51	Whirlpool G.	30 min	RD100-N
12, t	M-57	Ring N.	10 min	RD100-N
12, m	NGC-6302	Bug N.	11 min	RD100-N
12, b	NGC-3242	Eye N.	10 min*	RD100-N
12-13	M-42	Orion N.	30 sec	K-400
13	M-17	Omega N.	20 min	RD100-N
14	M-11	Wild Duck Cl.	10 min	RD100-N
15	NGC-5128	Centaurus-A	30 min	2415-H

*taken at f/15

Photographs were taken with the 24-inch f/15 Cassegrain Air Force telescope and an 80mm diameter f/4 focal reducing lens, at f/6.5. RD100-N is Fujichrome RD100 slide film developed as a color negative in Unicolor K-2 chemistry for 4.5 minutes at 38°C, and hypersensitized in 8% forming gas at 16 psia for 16 hours at 46°C on an open reel. K-400 is gas-hypered Kodak Kodacolor 400. 2415-H is gas-hypered Kodak Technical Pan 2415. The color separations for this article were prepared from slides made by rephotographing the negatives on Kodak type 5072 high-contrast color-negative copy film.





Do Supernovae Trigger Star Formation?

by Martin Cohen

Photograph by M.A. Gordon

The evening is ruffled by a breeze as the setting Sun lights the computer keyboard with a yellow glow. Racks of warmly humming electronics line the walls, and arrays of red and orange digits flutter as the displays update. A rattling sound penetrates the air-conditioned room where the computer resides. Through the window, an 11-meter-diameter dish antenna is briskly rotating to point toward a specific part of the sky. In the light wind, the white fabric dome flutters and shakes against its supporting lattice of metal rods.

Inside, a black and white television monitor is "refreshed" — it goes completely blank, and then gradually flashes words and figures into place to fill the display. These report the status of the dish: azimuth, elevation, frequency of the radio receiver, ambient temperature, beam size — all calibration figures for the antenna and receiver.

We are at the National Radio Astronomy Observatory (NRAO) facility on Kitt Peak, 40 miles southwest of Tucson, Arizona. Thousands of feet below, the desert rolls dustily toward vague horizons, cut by dark crinkled ridges and ranges of mountains. To the northeast sprawls Tucson, a luminous carpet as night advances.

In its huge white dome, the radio antenna peers toward the constellation of Monoceros, kept on target by its computer. High frequency radio waves, which left this particular region of our Galaxy almost 5,000 years ago, wash silently against the giant ear and are focused to where a small and very sensitive device, suspended in front of the dish on long metal legs, receives the radiation.

Why have we come to Arizona?

The Monoceros Loop Nebula is a large circular structure that adjoins the Rosette Nebula, seen overexposed at top left. Arrows indicate new stars. Photograph by John Meaburn.

Right: Part of the Veil Nebula, a supernova remnant in Cygnus. This page: The shape of the nebula hints at its explosive origin. Photos from Hale Observatories.

The story behind this trip is a combination of the life histories of stars and current theories and techniques in observational astronomy. As you read this, stars are being born and stars are dying; the cosmos is at work on a massive scale. Our Galaxy is a vital, dynamic entity of some one hundred billion stars. A great population of vast, tenuous, hazy clouds resides in the disk of this enormous catherine wheel, a hundred thousand light-years across.

Mostly composed of hydrogen gas, these clouds contain other gases, such as carbon monoxide, as well as a seasoning of small dust particles. They are visible in photographs as dark "holes in the sky" amid the multitudes of background stars. Light from objects behind the clouds has been scattered and absorbed, obscured by the dusty fog.

Like all matter, these clouds are subject to self-gravity — the mutual tug of one bit of cloud on another. If any fragment of these clouds were somehow to begin collapsing on itself, it might continue to do so for perhaps hundreds of thousands of years. Eventually, in the dense central core of the fragment, the material could become compressed and hot enough to begin fusing hydrogen atoms into helium. A star would be born.

Over tens of millions of years, a dust cloud will constantly generate young stars, thereby depleting its reservoirs of gas and dust. As the gas is used up and clears away, a cluster of stars will eventually become visible. The combination of strong stellar winds — similar to the solar wind, but far more powerful — and fierce radiation will finally disperse the remnants of the parental cloud.

A few million years later, the most massive and shortest-lived of the cluster stars will have exhausted their internal supplies of nuclear fuel. No longer able to provide adequate central pressures to withstand the crushing weight of their outer layers of gas, they will collapse catastrophically and then explode, spewing into space all the heavy elements "cooked up" throughout their lives by nuclear reactions in their extremely hot cores. These rich chemical ejecta spread slowly through the Galaxy and eventually congregate into new clouds where they seed the next stellar generation.

The catastrophic explosion of a supernova sends violent shock waves and blasts of radiation through the interstellar medium — the near-vacuum that lies between the stars. Suppose such a blast wave were to encounter a cloud of gas and dust. Could it give the cloud a firm enough push to trigger it into collapse and ultimately into forming stars?

Before seizing on this answer, we ought to take a look at some of the ideas that astronomers have proposed before now — if only to put this latest model into perspective.

It's no secret that ideas in astronomy and many other fields often gain credibility by popular appeal — a sort of "science-by-bandwagon." For example, a decade ago, the idea of spiral density waves gained widespread interest among astronomers almost overnight. These were thought to be galaxy-wide waves in the density distribution of disk material. In the model, the waves compressed clouds in the galactic plane and thereby promoted their collapse to stars. Since these waves were spiral in shape, the pattern of star formation they induced in the Galaxy was also spiral — and astronomers could trace it by the distribution of hot young stars.

These waves had the appeal of existing simultaneously over very large distances and helped explain the extremely wide expanses over which young stars, open clusters, and ionized hydrogen regions occur. In short, the notion was that density waves act as "global organizers" of galactic structure and, in themselves, were the triggers of star formation.

Then in about 1975, a new idea suddenly gained currency — sequential star formation. This model envisioned the birth of stars as a sort of cosmic disease that nibbled away at a giant cloud of gas and dust. Watching such a process at work on a cloud, we'd see several simultaneous stages in the development of stars.

First, we'd find full-grown young clusters of massive stars at the outside of the cloud, then a region between them and the cloud where a wave of ionization is advancing into it, driven by the ultraviolet radiation of the already-formed stars. Finally, we'd see the dark cloud itself, rich in molecules readily detectable by microwave radio emission, and studded with sources of infrared radiation. These infrared sources represent the birth sites of new high-mass stars which are still heavily shrouded by dust. This process operates sequentially and is self-perpetuating — given an initial star of high mass — since it preferentially produces high-mass stars from the cloud.

Kitt Peak National Observatory photograph

The model in vogue today is the supernova trigger. Proponents claim it may be capable of yielding stars over a wide range of mass — which more accurately fits the cosmos as we see it. The mechanism goes into action when the high-speed shock wave and debris from a dying star — a supernova — expand out into the interstellar medium. Before its momentum is lost, the shock wave will sweep up a large volume of material. Proponents of the model argue that eventually the blast may compress the mixture of pre-existing clouds and plowed-up matter to such a density that self-gravitation can take over and finish the process of star formation.

The antecedents of the idea go back about thirty years to the prophetically perceptive astronomer Ernst Opik. Years later, Rudolph Minkowski wondered about the intriguing arcs and chains of stars seen at the rim of the Veil Nebula in Cygnus, a giant gas-shell remnant of a supernova explosion. However, what really stimulated a resurgence of the supernova trigger model were studies of a large expanding shell of ionized gas in the constellation of Canis Major. At one edge of this shell lies a complex of dense dark clouds, coupled with stars, some of which still illuminate the material from which they presumably formed. Astronomers William Herbst and George Assousa studied the region and concluded that a supernova had triggered the clouds at the shell's edge into collapse and produced the associated stars.

But before we adopt this model, we should bear in mind that their work is still controversial, and several unanswered questions linger. While the Canis Major shell may be the product of a recent supernova, it does not have the radio emission spectrum usually associated with one. Conceivably, it might have lost this in gradually merging with the interstellar medium, but in that case there is no clear evidence for an amount of neutral gas that ought to have been plowed up. Nor has any pulsar, the spinning collapsed remnant of the star that blew up, been found within the region — or any other identifiable stellar remnant.

The stars in the clouds on the edge of the ionized shell of gas do not appear any younger than other "field" stars found in the general region, which were presumably not triggered into collapse by any external force. Even if the stars at the edge of the gas-shell were young, this ignores the delay that might occur between the arrival of a blast wave and the initiation of collapse. If a blast wave triggered the birth of stars, then these should form some distance away from the supernova itself, and the older the expanding gas shell, the farther from the center should be the stars created by the blast. But this displacement has not been found either in the Canis Major region or in other regions where supernova-triggered collapse has been suspected. And that is one criticism of this model.

A colleague of mine, Leo Blitz, has raised a number of other criticisms. He is a radio astronomer, especially experienced in the study of carbon monoxide and other molecules in dark clouds. My own research interests during the past decade have often focused sharply upon young stars. Both of us wanted to investigate the supernova trigger mechanism: he because it involved molecular material, and I because I had found some intriguing results in the stellar nursery closest to the Sun — the Taurus-Auriga dark clouds.

The structure of these nearby clouds resembles a series of beads on a wire, the "wire" being a broad elongated ridge of gas and dust and the "beads" denser blobs in which young stars are visible. Long study has revealed that the stars in each bead appear to be about the same age. If the supernova trigger model is correct, how could one supernova explosion have controlled the formation of stars along this ridge — almost 60 light-years in length?

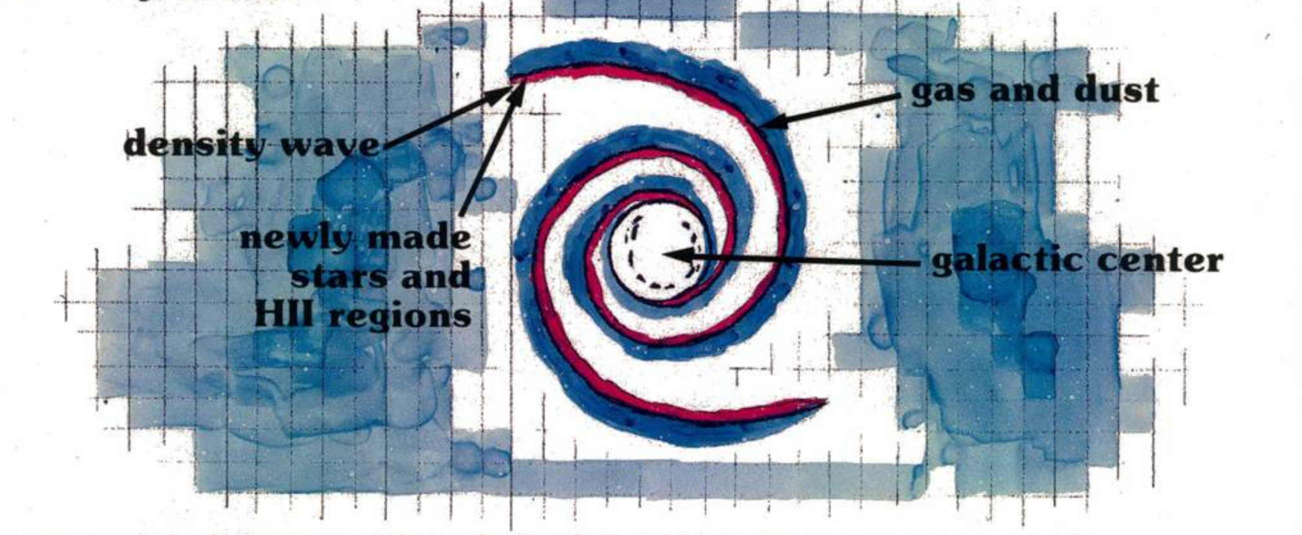
I turned to another colleague, Harold Weaver, who had been studying galactic structure by means of neutral hydrogen clouds, which he was observing with radio telescopes. He had tantalizing evidence for an expanding shell of gas, with one edge approaching us and the far side expanding more slowly into the Taurus clouds. Its shape and internal motions certainly suggested a supernova explosion, and the deceleration of material on the rear part of the shell argued that it was interacting with the densely-crowded stellar nursery. As the evidence mounted, it began to look as if my efforts to avoid the "supernova bandwagon" were bringing me full circle!

To decide the matter, Blitz and I worked out a set of crucial questions and selected a region to search. Basically, we were looking for a *bona fide* supernova remnant that had interacted with dark cloudy material in the recent past and had produced young stars.

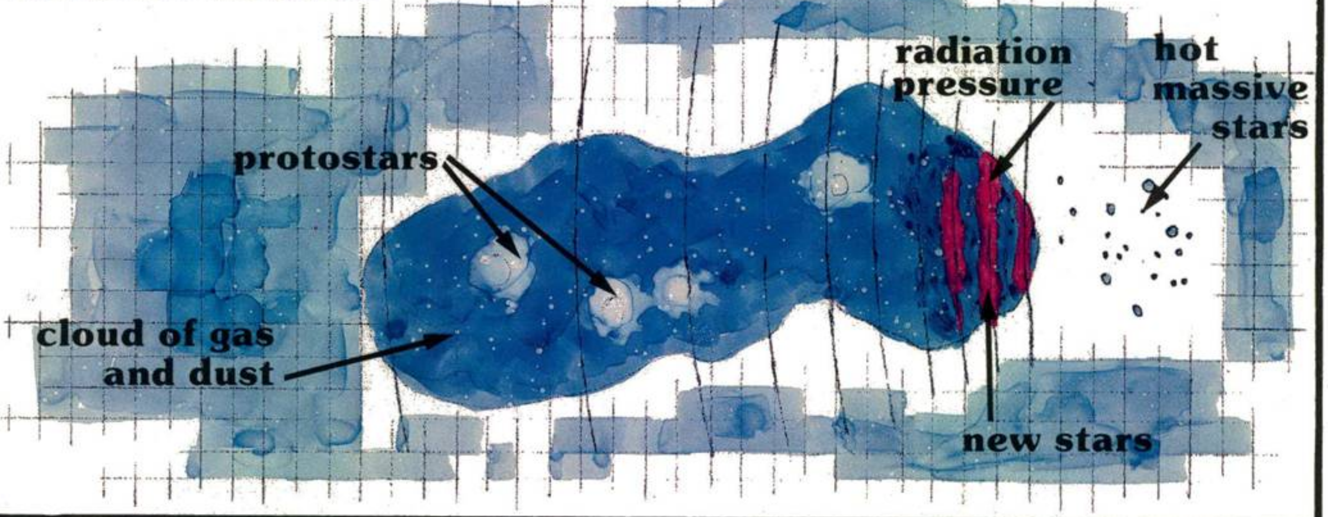
The admission requirements were pretty stiff. First, we had to find a gas-shell whose supernova origin was convincing. Then we would have to

What Triggers Star Formation?

Density Waves


gas and dust
density wave
newly made stars and HII regions
galactic center

Radiation Pressure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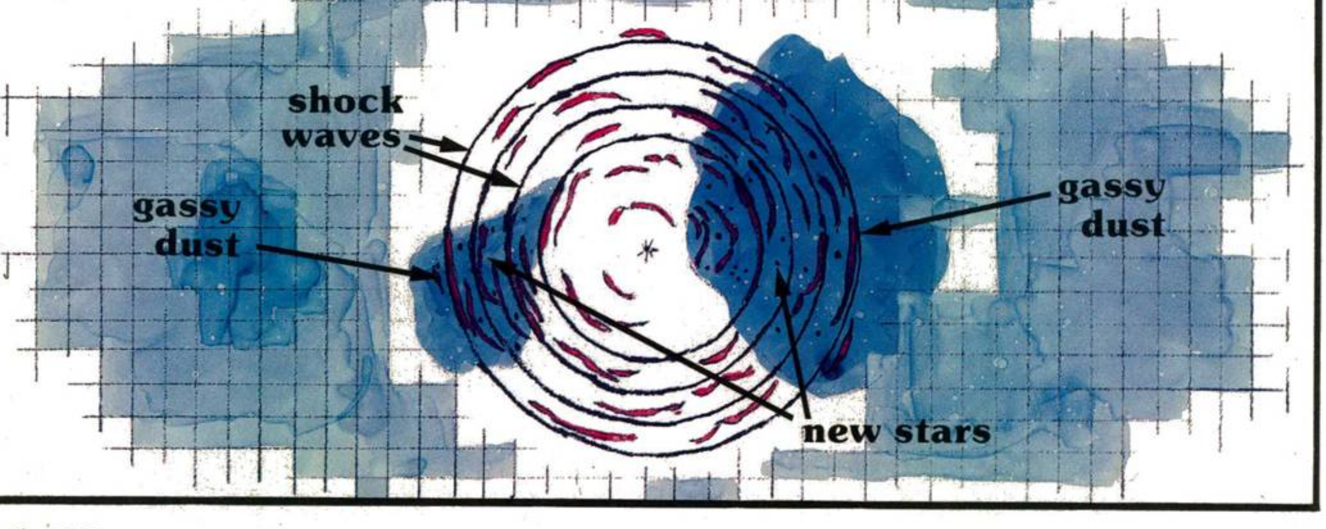
shock waves
gassy dust
gassy dust
new stars

Lick Observatory photograph

establish the physical proximity of the dark clouds and the expanding gas-shell. As another prerequisite, interaction between them had to be clear-cut. Furthermore, any delays between the arrival of the blast wave from the supernova and when the first stars formed had to be investigated. Lastly, we had to demonstrate that stars in those clouds which had suffered disturbance were young enough to be a by-product of the blast.

With this as an outline, we chose the Monoceros Loop Nebula as a testing ground. Its direction and distance place it adjacent to the Rosette Nebula, about 5,000 light-years away. The Loop is a roughly circular structure of filamentary gas, some 250 light-years in diameter. Its shape alone suggests it is a supernova remnant, and radio emission from the shell corroborates this. Photographs of the Loop taken in the light of ionized hydrogen clearly reveal small, dense, dark clouds throughout — some apparently close to the luminous remnant's rim and others projected against its inner portions.

Scrutinizing photographs of the Loop and comparing blue, red, and hydrogen-light pictures, we tried to find faint red stars that either were associated with the clouds — through involvement with small bright nebulae — or those that appeared hydrogen-bright, a characteristic of young stars comparable in mass to our Sun. The stars we found provided a basic list of objects for more detailed investigation.

We planned three parallel studies. At California's Lick Observatory, we used the 120-inch reflector in collaboration with Leonard Kuhi to obtain optical spectra of the stars. From Kitt Peak, I investigated their infrared properties. Lastly, Blitz and I headed for the NRAO microwave antenna, also on Kitt Peak, to study the motions of the dark globules by examining the Doppler-shifts of their carbon monoxide (CO) molecules.

At present, the work is still in progress. Only a few of the stars have been investigated at optical wavelengths, and only one of them presents clear evidence of being a young object. This star possesses a significant amount of infrared emission, which suggests youth. And we know it is in the cloud because it illuminates a faint arc of nebulosity. The radio emission of molecules from its direction speaks for an on-going interaction between star and cloud, possibly by means of a strong stellar wind that is colliding with a dense gas ridge and creating the nebulous arc.

Elsewhere in the region, we found firm evidence that the gas in the globules inside the Loop has been disturbed by comparison with the gas in the globules which have yet to feel the blast wave. More specifically, globules outside the rim of the Loop are cold and the material is moving only at one or two different speeds. By contrast, globules within the Loop are hotter and show more — and higher — velocities in their molecular emission.

Carbon monoxide is ideal for studying the dynamics and internal state of dark clouds. You find it everywhere; it is abundant and readily detectable with a radio telescope. And CO molecules having different isotopes of carbon and oxygen can be investigated in some regions as well. The Doppler shift alone is highly informative, since it shows the velocities of gas within each dark globule or portion of an extended cloud. Even if several velocities are simultaneously present within a cloud, they can be disentangled if your receiver electronics can discriminate enough between frequencies.

When we compare where the different isotopes of carbon monoxide lie in the clouds, we learn about their temperature and density — even a single molecular isotope map provides vital information on possible internal sources of heating. For example, a hot cloud is likely to contain an embedded large star — as yet invisible, but betraying its presence by the distribution of isotopes — and a cold cloud argues that few, if any, stars of high mass have recently formed.

Unfortunately, we haven't yet located the young stars in the disturbed cloudlets at optical wavelengths which would enable an age to be determined for them. Maybe we haven't searched hard enough — or perhaps not enough time has passed for the creation of full-fledged stars. If that's the case, then infrared studies — which probe the interiors of the globules — would be more useful than optical methods.

This is where matters stand for now. Whether the supernova model is confirmed, modified, or superseded, we are optimistic about the direct observational approach. Science works by tempering its theories with facts, and so, despite its successes, a lot more work lies ahead before we can call this model other than controversial.

Martin Cohen is a British astronomer at U.C. Berkeley and NASA's Ames Research Center whose research interests center on stellar evolution. "Stellar Formation," his last article for ASTRONOMY, appeared in September 1979.

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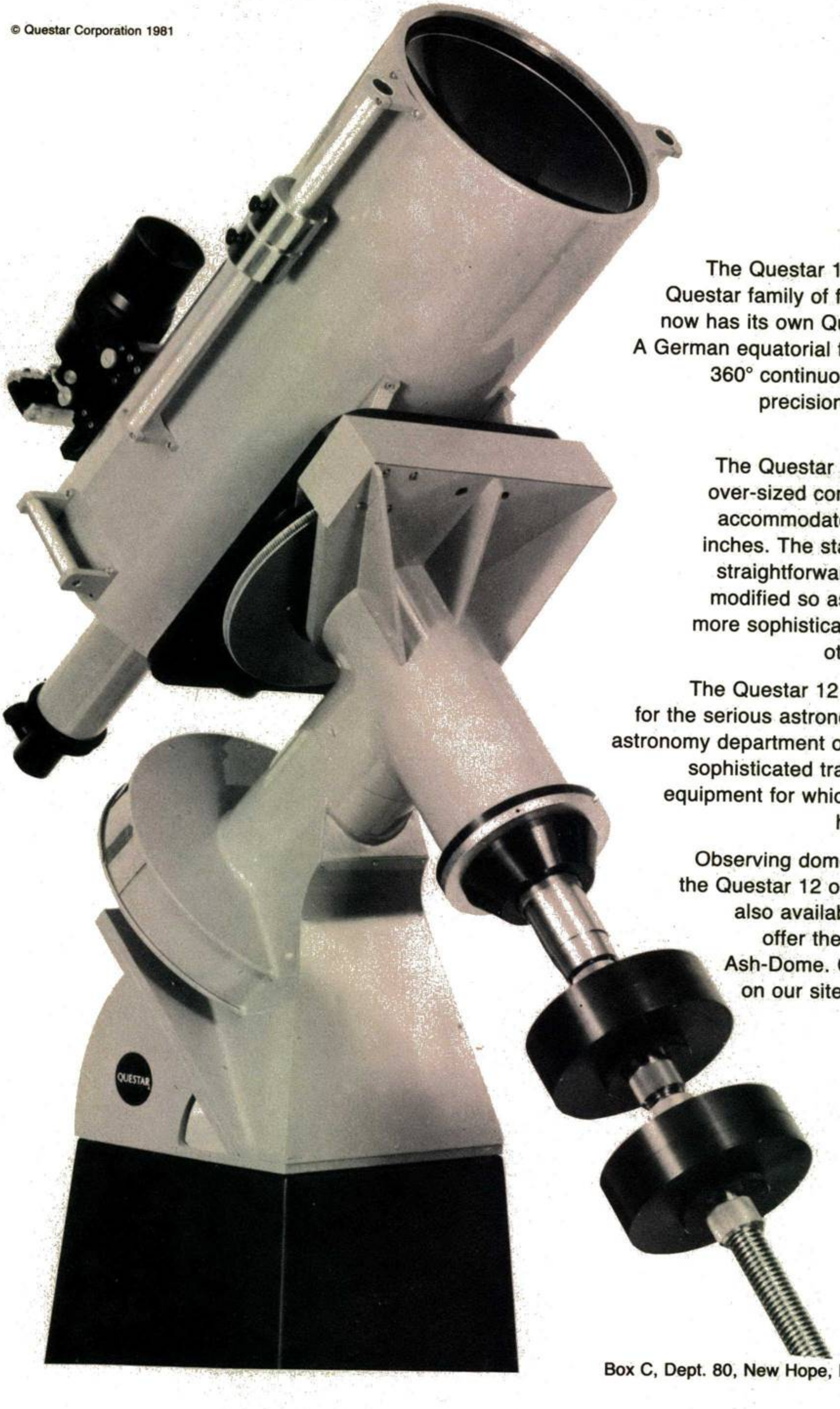

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ASTRONOMY FORUM

A Night to Remember

The Moon had gone down at three in the morning, and I was bundled in my down bag under the dark desert sky, fast asleep on an asphalt parking lot that was as dark as the surrounding lava flows.

Content in my cocoon, I was at Craters of the Moon National Monument on tour with the Sidewalk Astronomers. After our evening slide show in a beautiful outdoor amphitheatre, with the bright Moon overhead, one of the many park visitors who stayed to look through the telescopes asked if he could return after the Moon had set to see some of the deep-sky objects that were then overwhelmed by the brightness of the Moon.

Reluctantly, I had agreed, staring across in the direction of my sleeping bag, arms crossed against the cold. "Above and beyond the call of duty," I thought between yawns, but the beautiful clarity of the night soon began to work its special magic on me. By the time I was ready to sleep, I was looking forward to waking, even at such an ungodly hour.

So, as I lay there, zipped in and finally warm, there was a tap on my shoulder. I came back to the consciousness of the cold night as though I were rising upward from the bottom of a great, comfortable lake. I rolled over onto my back. Had the Moon set? The stars cast such an intense light that I couldn't tell! It was windless, but deathly cold. I crawled out of my bag and into my down jacket like an expert arctic traveler, for many nights of stargazing on the tops of Sierra mountains had taught me a few tricks about self-preservation.

As I set up the ladders, I noticed that although it was summer, it was so late at night that we stood under an autumn sky. Orion was rising; the Crab Nebula and the Andromeda Galaxy were well up; and Mars shone unblinking, like a steady red light near the horizon.

Because of the brightness of the stars, I knew within minutes that I had never been under such a dark sky before, and my excitement mounted as I swung my 24-inch telescope, Delphinium, in the direction of the Andromeda Galaxy. I centered this beautiful nearby spiral galaxy in the finder, had my midnight partner help me readjust the ladder, and ascended to the eyepiece. A faint glow, a slight movement of the front end of the telescope with my hand, and there it was! Because of its brightness, I thought at first that I must be looking at the central bulge, but the shape was wrong. Suddenly, I knew, and cautiously, like one on the edge of a very great and somehow frightening discovery, I tenderly moved the telescope. Slowly, the central bulge slid into view, filling the eyepiece so brightly that I gasped and had the sudden urge to wake up everyone within earshot and beyond to come and share the view. I don't know how long I hovered at the eyepiece, scanning the galaxy over and over again like an obsessed professional trying to prove a private theory. I counted the dust lanes, astounded that the nebulosity stretched out more than seven eyepiece fields in the disk direction at 150 power.

My patient midnight friend who had, after all, prompted this late night rendezvous with the stars, stared up at me with one foot on the ladder, obviously eager to clamber up and see what all my commotion was about. So I finally relinquished the eyepiece and descended wondering what we should look at next. I woke up a happily slumbering Sidewalk comrade John, who was better-versed than I in the locales of some of the more dimmer galaxies, and he, like the saint that he is, burrowed into his coat and followed me out to the telescopes. I insisted that we try to find M-33, a nearby but very dim galaxy with spiral arms that faces us head-on. We had looked for it at Zion National Park, where the telescopes had been set up in the bottom of a canyon, and the cold winds coming off the cliffs at night had greatly disturbed the seeing conditions. There it had been barely visible, so faint that shape was impossible to determine, and we had to wonder if we were really seeing anything but a projection of a wishful imagination. In spite of this first vague introduction, M-33 had become a sort of "pet" galaxy to me, and we had tried, without much success, to get a better showing at several of the other parks we had visited.

John expertly swung the telescope in the direction of a dark patch of sky. We helped him move the ladder, and he ascended. I chatted rapidly about how I'd love to be able to see the spiral arms of this elusive galaxy, and the park visitor, who wore a large brown coat, listened with a puzzled expression. Perhaps he was wondering why I was so anxious to see its spiral arms when Lick Observatory had taken a beautiful photograph of it that I had shown in the slide show.

"Photographs — poof!" I would have answered him had he spoken his thoughts. Who wants hours of light-gathering, paper and chemicals? Give me what I can see with my own eyes, what shines above me (or BELOW me if our

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galaxy is falling in that direction), what comes to greet me from across the silent expanses of a nearly empty Universe, light that has traveled and traveled to finally enter my own small eye and fill this human brain with wonder and perhaps some understanding.

"There it is," said John. "You're gonna like this, Ruth." He had taken great pleasure over the past weeks in ribbing me about my fondness for such an underdog deep-sky object, and I grinned sarcastically at this passing comment. I fairly jumped up the six-foot ladder, and suddenly I was no longer cold. My hands were blue and stiff, my face stinging, but I no longer noticed. For the sight I witnessed before me — reflected from a hand-ground mirror made for love of the sky — filled me with bigger thoughts. Was I seeing the great M-101 that rides in the sky near the Big Dipper? But it was the wrong part of the sky. The spiral arms were dim, but so clear! And the great hydrogen-cloud birthmarks that distinguish M-33 were immediately obvious. "Oh, my Lord!" was the only thing that came from my mouth, partly an expression of surprise and delight, partly an expression of real reverence. That one sight, seen while standing on a ladder in the desert freeze, made my evening — made the whole tour for me.

I just had to wonder if some intelligent being on some planet around some star in that lovely little nearby galaxy was looking back in my direction. I was coaxed down after a time, and we saw many other things before dawn swept in and carried us back to our Sun telescope, back to greeting the many park visitors with news about our nightly programs.

The zodiacal light was very bright just before dawn, brighter than I have ever seen it. The man in the brown coat, whose name I have long forgotten, but to whom I am forever grateful, thanked us heartily and returned homeward through the Idaho desert in some unknown direction.

The next couple of nights passed more calmly; the Moon set so close to sunrise that deep-sky viewing was out of the question.

Ruth Ballard
San Francisco Sidewalk Astronomers
San Francisco, California

Requiem for a Comet Probe

It was dying.

The Sun was killing it. Bit by bit, every seventy-six years. The Sun was stealing its body.

Once it had been inviolate. Approaching the Sun but once in countless millions of years, its majestic orbit had reached half way to forever before again nearing that disk of deadly heat. But after Jupiter had intervened, its orbit became puny, confined to the inner system. The Sun's heat and hot plasma breath boiled its surface and blew the resulting gas and dust toward the stars. What a fine tail! — but it meant disaster. From a future once reckoned in billions of years, the comet now had but a few thousands, perhaps tens of thousands, of years to live.

And even greater disaster approached. Four motes of metal and plastic, guided by minute tails of radio energy that reached from the third planet: the water planet. The comet knew well what this could mean: water-based creatures were almost ready to leave their world. For a comet made primarily of water and other volatiles, in an inner system poor in volatiles, it could spell an even earlier end. In a few short years the comet might well become a resource, a tool to support the water-based creatures in their colonization of the inner Solar System.

Not exactly a brilliant future for a healthy young comet.

Such might be the sad history of a thinking comet: Comet Halley to be exact.

But I have an even sadder story to relate, one that deals with the planet Venus as well as with Comet Halley. It also deals with the politics of those water-based creatures on the third planet, the politics that determined just how many of those exploratory vessels that so bothered the comet in our story would actually fly.

Once there were to have been five vessels, not four.

Some of the water-based creatures have an organization to which they have assigned all duties relating to exploring the solar system — a relatively low priority activity. This organization is called (for reasons known only to the water creatures themselves) NASA.

In the late 1970s and early 1980s, NASA, with the help of the scientists from all over the world, decided that a mission to map the surface of Venus (the Venus Orbiting Imaging Radar or VOIR) should have a priority over a mission to photograph and explore the immediate environment of Comet Halley (in its latest incarnation, the Halley Intercept Mission or HIM). This decision made perfectly sound scientific, economic, and engineering sense. But it was a political disaster, I think, for both NASA and the pro-space movement in general.

NASA's scientific goals have remained essentially unchanged for the past two decades. As far as planetary science is concerned, the primary goal has been the establishment of a data base for comparative planetology. This relatively new science involves learning as much as possible about as many as possible of the planets and planet-like moons, teaching us how planets work in general. This, in turn, should help us study individual cases, such as Earth. When we look at it in detail, we see that NASA has a laudable, well-organized, and systematic plan for exploring the solar system — a plan that should allow us to learn the most while expending the least effort.

Under this plan, VOIR is clearly the next mission that will be undertaken. We know less about the geology of Venus than about any other planet out to and including Saturn's moons (except Titan) because of the thick clouds and high atmospheric pressures that make the exploration of Venus and Titan so technically difficult. So if we are to advance comparative planetology, we need to know more about this planet most like Earth in general physical structure and placement in the solar system, yet least like Earth in everything else.

There is little doubt that the surface of Venus would be an interesting place to explore. A carbon dioxide atmosphere at a temperature of 470° Celsius and with a pressure of some 90 times that of Earth continues to hide possible continents, volcanoes and canyons from definite identification.

The VOIR mission could give us 600-meter resolution radar photographs of most of the venusian surface (missing only one pole which would be covered in an extended mission) and about two percent of the planet could be scanned with a resolution of down to 150 meters. Further studies of the venusian atmosphere would also be conducted. The VOIR spacecraft would be one of the largest planetary missions ever undertaken and would be dominated by a massive radar antenna. VOIR could

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also demonstrate for the first time the technology for using the atmosphere of a planet to slow a spacecraft to orbital velocity — an important new technique that could allow a greater payload within the same spacecraft mass by saving fuel. It is clear that VOIR would be an important and exciting mission.

But HIM would be an important and exciting mission too. Astronomers think that comets contain the oldest accessible material in the solar system and could tell us much about conditions when the planets formed. Thus the knowledge gained could be very important for comparative planetology. Technologically, it would also be a highly demanding mission — far superior to those planned by Russia, Europe or Japan. (Not to denigrate any of these valuable but limited missions — they are, after all, far better than nothing.)

Using an exclusively American technique, HIM would photograph the comet's nucleus against the stellar background as it approached, and astrogate far closer than any of the other missions could risk at the high relative speeds involved. And at $250 million, HIM is also far less expensive than VOIR — probably one of the cheapest planetary missions.

However, it is easy to understand NASA's reluctance to drop or delay VOIR in favor of HIM. NASA originally planned a far more ambitious program of cometary exploration. Ion engines (SEP for Solar Electric Propulsion) were to be used for a high-energy rendezvous with Comet Halley and perhaps even a landing on the nucleus. When NASA saw it could not get funding for this mission before celestial mechanics made it impossible, the agency tried again — this time designing a flyby and probe of Comet Halley and a rendezvous with Comet Tempel 2. The probe was to have been built by the European Space Agency (ESA), so the Europeans were understandably upset at the Carter administration's decision to delay SEP development, thereby making any comet rendezvous impossible. Hence ESA's unwillingness to let NASA in on its new Giotto probe, the best of the missions now planned for Halley.

All that's left for the United States is the last-chance HIM mission using surplus Mariner and Voyager equipment — a comparatively simple probe that would speed by the comet without close examination. In this context, HIM appears to be a waste of NASA's all-too-limited resources. Perhaps we should save our money until we can do it right — until we can fly something resembling the original comet rendezvous mission.

However, such a mission could not approach the scientific value of the original mission to Comet Halley. Why? Comet Halley happens to be the only young and active comet within reach of even ion engines. A mission to a comet other than Halley would study an older, less pristine, object.

Despite all this, I still think NASA could be making a mistake. It seems to me, for all of its scientific utility, VOIR was unlikely to have been overly popular with the public. Can radar maps of Venus have the pizzazz of a comet flyby with Halley? A troubled space-exploration program that is having difficulty justifying planetary missions before an economically troubled nation and a reluctant White House must consider how the public will react to any given proposal.

VOIR may have been the right choice. But it, too, has been cut from the NASA budget, delayed indefinitely. Perhaps it suffered some from lack of pizzazz. Man will not reach the stars on science and economics and engineering alone. Rightly or wrongly, man is driven as much by emotion as by logic — and emotion will take us to the stars. The indefinable "sense of wonder" is all important to the space program; it always has been, and in the future will continue to be, its driving force.

As four very small spacecraft disappeared once again into the night, the comet grinned. It had nothing to fear from the makers of these probes. If those probes represented all the resources the water-creatures were able to invest, they would never make it into space. Things were looking up! Now, if it could only get Jupiter to toss it back into the cold, dark, and above all, lonely emptiness between the stars. . . .

Donald F. Robertson
Sacramento, California

Moons That Weren't

With today's telescope technology, astronomers rarely "discover" ghost planets or false moons that they can neither confirm nor deny. But in the early days of observational astronomy, before photography, dedicated observers argued for and against the existence of disputed satellites of the known planets. Individual theories abounded, and many faithful observers spent their entire lifetimes trying to prove the reality of their solo discoveries.

In 1781 Herschel discovered Uranus, opening a new challenge for observers to pinpoint moons of that body. At the time, astronomers believed that Jupiter had four moons and Saturn had seven. Herschel discovered Titania and Oberon in 1787, but was convinced that there were more satellites, so he embarked on a dogged quest to locate those bodies. After a decade of strenuous effort with his primitive reflecting telescope, he announced his findings. In those ten years he observed 55 objects in close proximity to Uranus. Of those, he rejected 35 as stars, and 16 more disappeared without a trace. That left a set of observations consistent with four new satellites.

After sifting through all the data, relatively few observations remained for analysis, and he announced his discovery, along with orbital statistics, in 1798. Unfortunately, these four additional satellites were never confirmed, although John Lamont thought he glimpsed the outermost in 1837. The three new satellites discovered since Herschel's time (Ariel, Umbriel, and Miranda) all have orbits well inside his four, so Herschel's only true discoveries of uranian moons must be limited to Titania and Oberon. However, for forty years after the initial discoveries, no one but Herschel, Johann Schroeter and K.L. Harding even saw *those* two moons — attesting to this amazing feat of observation.

The independent observations of William Lassell and the elder Otto Struve in 1847 raised the hopes of recovering two of Herschel's four lost moons. The Englishman Lassell observed four uranian moons — Titania and Oberon, which he called I and II — and also what he assumed to be Herschel's innermost and intermediate satellites, which he called 1 and 2. Lassell drew them in his journal on November 6, 1847, but difficulties with the weather only allowed him a few observations in the following two years.

Struve, on the other hand, saw only three satellites, and suggested that the discrepancies in Herschel's record were due to the faintness of the objects, and the limited telescope technology of the day. Besides Titania and Oberon, Struve observed what he thought was Herschel's innermost satellite. But the period that Struve determined for this body is closer to that of

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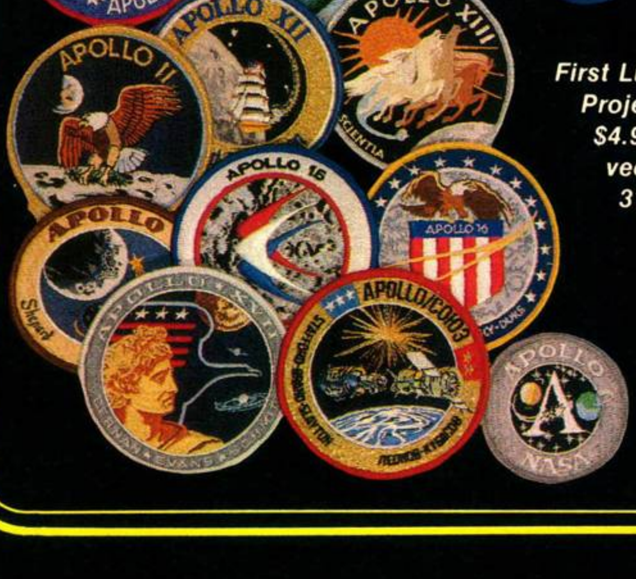

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Umbriel — which was yet to be discovered. William Dawes attempted to reconcile the observations of Lassell and Struve and concluded that there must be three satellites interior to Titania and Oberon, which he designated a, b, and c. He concluded that Herschel probably saw c. By 1851 Lassell had confirmed the discovery of Ariel and Umbriel. In reference to Dawes's work and his own observations of 1847, Lassell stated, "I never thought my own observations sufficiently connected and definite to be worthy of the ingenious and elaborate discussion given by my friend M. Dawes.

"The most probable explanation of the former observations of Struve and myself is that we sometimes observed one satellite and sometimes the other. This would explain the difficulty in reconciling the observations."

Lassell addressed himself to the possibility of finding more satellites after his discovery of Ariel and Umbriel, and with almost prophetic precision stated, "I cannot assert that Uranus has no interior satellite besides these two; but I feel confident that if they exist, they must be very much fainter, or they would not have escaped my notice." A century later in 1948, Lassell's opinion was vindicated by Gerard Kuiper's discovery of the much fainter Miranda. Following this discovery, Kuiper and Daniel Harris used the 82-inch McDonald telescope and searched a radius of 35 minutes of arc around Uranus, but found no new satellites down to a limiting magnitude of 20, settling once and for all the mystery surrounding the lost moons of Uranus.

Beyond Uranus lies Neptune, which has two known satellites — Triton, discovered in 1846 by Lassell, and Nereid, discovered by Kuiper in 1949. These two are the only confirmed neptunian moons, although there have been other sightings.

In 1851 Lassell thought he saw a second satellite, and wrote: "I had also, with power 614, a strong suspicion of a second satellite, but though I saw a point there positively for a short time, I could not afterwards see it." Lassell never did see it again, and concluded that his observation had been in error. In 1892 John Schaeberle, using the Lick Observatory 36-inch refractor, also saw a possible neptunian satellite, but again subsequent observations proved this was not a satellite of Neptune. It seems certain that neither Lassell nor Schaeberle could have detected Nereid because neither had a large enough telescope. Since those early times, searches with the Mount Wilson 60-inch, the McDonald 80-inch, and the Palomar 200-inch have not detected any moons brighter than magnitude 22.5 — corresponding to an upper diameter of 160km.

Until recently, astronomers believed that the most distant planet in our solar system had no moon. In the 1950s unsuccessful searches for a plutonian satellite were made using the Mt. Wilson and Palomar telescopes. However, on June 22, 1978, James Christy of the U.S. Naval Observatory noticed a strange elongation in the photographic image of Pluto. After examining earlier negatives he found that this elongation appeared regularly. The occurrences of these elongations indicated a period of 6.4 days — the same as Pluto's photometric "rotation period." On July 6, J.A. Graham confirmed the discovery with the Cerro Tololo 4-meter telescope. Christy has named the moon Charon — after the mythological figure who rowed the dead souls across the river Styx.

Leverrier urged astronomers to search for transits of an intra-mercurian planet during total eclipses of the Sun.

We also encounter many astronomical legends concerning the existence of planets very close to the Sun. The first hint that there might be a planet closer to the Sun than Mercury came when astronomers in the nineteenth century determined that Mercury's rate of perihelion advanced 38 seconds of an arc per century — faster than theory would indicate. In 1849 Leverrier suggested that some mass or masses interior to Mercury's orbit must be perturbing the planet's motion. In a note to the French Academy of Sciences in 1849, he expressed his puzzlement regarding this discrepancy. Leverrier urged astronomers to search for transits of an intra-mercurian planet during total eclipses of the Sun. The search for Vulcan began.

A rural physician and amateur astronomer named Lescarbault had seen the transit of a small, round object across the Sun earlier that year. After being contacted by Lescarbault, Leverrier hurried to meet the man and examine his discovery. Leverrier checked Lescabault's instruments and observations, found them satisfactory, and was convinced that his theoretical planet had been found. He determined that the planet had a period of 19.7 days and a mass $^1/_{17}$ that of Mercury with a maximum angular separation from the Sun of only eight degrees.

Although this newly discovered planet did not have enough mass to explain the perturbations of Mercury's orbit, Leverrier was convinced that Vulcan had been found. Leverrier was instantly hailed as a genius by the astronomical community. Astronomers sifted through their old solar observing records looking for previous transit sightings of Vulcan. A number of them were found allowing astronomers to calculate that the next transit would occur between March 29 and April 7, 1860.

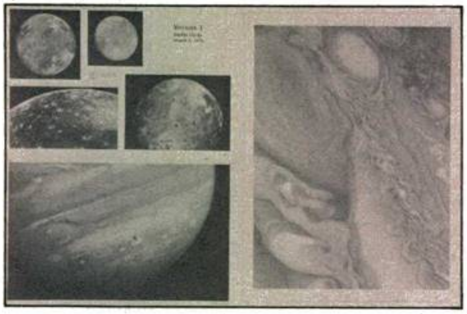
Astronomers the world over kept their eyes glued to the eyepieces during this ten day period, looking for the tiny shadow of Vulcan against the Sun. They saw nothing, and failure to detect any transit of Vulcan threw the scientific community into an uproar. Doubts of Vulcan's existence were raised and opposing factions began to form. Through it all Leverrier maintained the existence of Vulcan. By the mid-1860s Vulcan was the subject of much confusion, and most astronomers remained uncommitted.

In March 1877, Leverrier predicted another transit — this time supported by improved orbital calculations. He reminded astronomers the world over of the impending transit and suggested that searches be made. His request was accepted, and even Astronomer Royal George Airy lent his support. For three days astronomers watched the Sun for a tell-tale shadow, but they saw nothing.

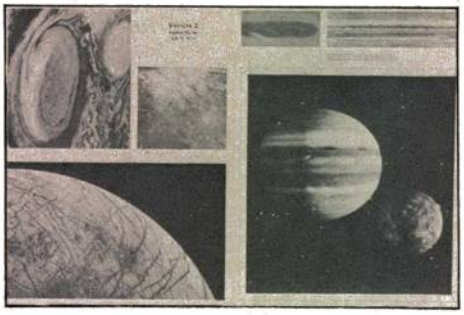
Leverrier's death that same year silenced Vulcan's major proponent. Even so, interest remained high and several additional unconfirmed reports trickled in. By the end of the century interest in Vulcan and faith in its existence had waned, and the death blow came in 1915 when the advance of Mercury's perihelion fell within Einstein's prediction of general relativity and experimental error. Observation and theory were once again in agreement — there was no Vulcan.

Dale Cruikshank
University of Hawaii
David Kasle
Draper Laboratory
Cambridge, MA

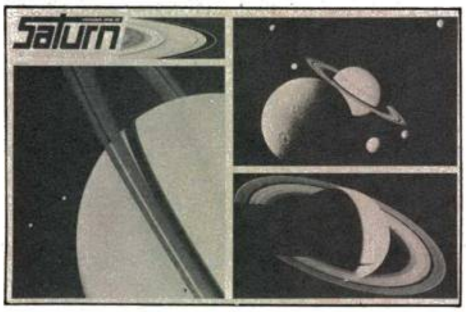
Visit Jupiter and Saturn With Voyager 1 and 2



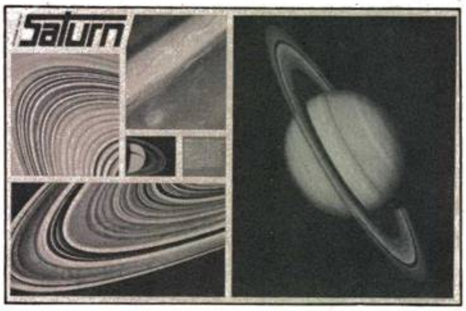
JUPITER 1. Images from Voyager 1 of the Red Spot, floating satellites against the planet and close-ups of the fabulous Galilean moons.



JUPITER 2. Six more unduplicated photos of the miniature solar system from Voyager 2. A perfect complement to the Voyager poster at left.



SATURN 1. The jewel of the solar system reveals its hundreds of rings, radial spokes and curious collection of satellites.



SATURN 2. Stunning images of a giant among planets — with a mystery and beauty all its own.

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ASTRONOMY IN FOCUS

Rename NASA?

Sir / It sounds like it's time to rename NASA. How about the Space Shuttle Trucking Company? If the administration's proposed budget cuts go through, the name would best describe what remains of the U.S. space program.

Shutting down our exploration of the solar system was disappointing, but even Voyager 2 — now at a distance of nearly a billion miles — is not too far away to receive its pink slip.

Living within a budget is important (and even with the proposed cuts, we still won't be doing that), but I'm starting to wonder if such a shortsighted nation really deserves the benefits of an effective space program.

It's unfortunate that the scientific community, historically the low man on the totem pole of government priorities, will yet again be the victim of a purse-string strangulation.

Steve R. Graham
San Antonio, TX

— *How about "National Aeronautics and Shuttle Agency?"*

Space Feeds People

Sir / Eric Carleen's letter (ASTRONOMY, December 1981) typifies the thoughts of those who profess indignation at the thought of funding "a glamorous space project at the expense of a mundane jobs program." This short-sighted view exhibits no understanding of the number of jobs created or maintained by the entire range of our space flight and planetary exploration programs.

Not only scientists, or those in other areas of specialized professional expertise, but skilled, semi-skilled and unskilled persons were (or still are) employed in space-related industries and could (or will) still be employed with the continuance of our efforts in those directions.

This employment provides them all with the purchase power to contribute to the income of other individuals, businesses and industries. People who are unemployed now, and who must be fed, were employed at the peak of our space programs. More will become unemployed with the cessation of programs now working.

The logical thought process shows that feeding robots and contributing to a closer observation of Halley's Comet result in feeding people. Money contributed does not disappear into space, but enters an economic cycle that provides continued employment for many and provides for the welfare (in the original sense of the word) of families without benefit of food stamps. Each additional contribution multiplies this accomplishment.

The prestige a nation has is not earned by the mere exercise of "feeding people," or establishing welfare programs. Rather, it is earned by affording people the opportunity to feed themselves. If this were not true, we would not have advocates of CETA training programs.

As the Viking Fund so aptly puts it, Mr. Carleen, "The Choice Is Yours."

Avonne I. Bradshaw
San Leandro, CA

Space Pays

Sir / I must comment on Eric Carleen's letter (ASTRONOMY, December 1981) in which he states, "We must. . . resist the temptation to fund a glamorous space project at the expense of a mundane jobs program." Does Mr. Carleen think that the money spent on the space program is loaded into rockets and blasted into space?

In fact, the money spent on the space program is used to pay salaries. It pays the salaries of scientists and engineers, of production line workers, secretaries, and janitors — and the salaries of hundreds of other workers. It kind of sounds like a "mundane jobs program," and a very productive one, at that. I'll choose the space program over an unproductive work project every time.

Richard O. Jones
Palatine, IL

Alpha Centauri System

Sir / Paul Patton's "Three Suns of Centaurus" in the January 1982 ASTRONOMY was an inspiring journey of the imagination — and a necessary prerequisite to an eventual real journey. I'd like to comment on two matters the article raised.

First, at a distance of only one sixth of a light-year (10,000 A.U.) from Proxima Centauri, Alpha Centauri A and B would both appear about 700 times, or 7.1 magnitudes, brighter than they do from Earth. Thus, from Proxima, Alpha Centauri A would shine at magnitude -7.1 and Alpha Centauri B at magnitude -5.8. These magnitudes are bright enough to cast shadows at night and would be almost painfully bright to the naked eye. Likewise, from A or B, Proxima would appear at magnitude 3.9.

Second: Another type of planetary system could readily exist within the Proxima Centauri system — a double planet. Double planets may be common, since two of them exist in our own solar system — the Earth and our Moon, and Pluto and Charon. The "day" of such a double planet would be the orbital period of the two planets around their common center of mass, and this could be short enough to avoid the roast/freeze conditions that would happen to a lone planet in synchronous orbit.

The three suns of Alpha Centauri most certainly warrant a visit. In addition to the dramatic daytime and nightime vistas of these stars, we'd also have a pretty fair chance to find habitable planets.

Thank you again for printing such delightful articles to stimulate the imagination.

Jack B. Marling
Livermore, CA

Centaurian Oort Cloud

Sir / Paul Patton's "The Three Suns of Centaurus," in the January 1982 issue of ASTRONOMY, is a very interesting and thought-provoking article. And other books available complement its content.

In chapter 4 of *The New Solar System*, Eugene Shoemaker implies that the Oort Cloud of comets could extend out to about two light-years from our Sun. In the Centaurus article, Patton suggests that a family of planets could orbit Alpha Centauri. To carry this a step further, why not a centaurian Oort Cloud around the whole triple star system?

If the Sun can retain a tenuous cloud of cometary material with an outer boundary roughly two light-years away, then the greater stellar mass of the Alpha Centauri system should be able to hold particles at least two or three light-years from its barycenter. This raises the possibility that any centaurian proto-comets more than a couple light-years from that system might wander into the Sun's Oort Cloud.

Could some of the comets that make one pass through the solar system on hyperbolic trajectories have started their journey in a cloud around Alpha Centauri? Perhaps they were dislodged from it by the gravitational disruptions of Alpha Centauri C, orbiting 10,000 A.U. from the heart of that system.

Furthermore, according to an earlier ASTRONOMY article, "Look Who's Moving into Our Neighborhood" (April 1979), the separation between the Sun and Alpha Centauri will be slowly decreasing until 30,000 A.D. when it will be at a minimum value of about three light-years. Any interactions between Oort Clouds of these stellar neighbors would therefore be on the increase over the next 30 millennia.

Patrick M. Stinson
Annandale, VA

Photographic Astrometry

Sir / I was pleased to see David Finley's "The Search for Extrasolar Planets" in your December 1981 issue. It gave a good feel for the importance some of us attach to such a search.

But one area of the article may give the incorrect impression that the photographic plate has become a casualty in the push toward advanced techniques. While the Allegheny Observatory MAP is, indeed, a technological advancement in the search for extrasolar planets, the photographic detector has also been improved via finer-grained emulsions, sensitization techniques, and density-scanning mensuration — and it is still very useful.

Today, we have two thirds of a century of photographic material available at some observatories. And we need data-sets that span similar intervals in order to find many of the aberrations that would suggest extrasolar planets. So, while it is true that much of this older material may be inferior in quality to what is now being obtained, these plates still harbor useful information, and we are now more capable of extracting it. We must also remember that not all the past problems of photographic astronomy were caused by the detectors used; some were the fault of telescopic effects.

The U.S. Naval Observatory has included some planetary searching in its astrometric program for almost a decade. Fairly conventional photographic and measuring techniques are still used — although some of this will change soon — but the major feature of the program is a specially designed telescope, the 1.55-meter astrometric reflector. We can routinely obtain parallaxes with accuracies better than 0.002 of a second for the stars with extended plate records. The perturbations that have been detected also have comparable accuracies.

In particular, the existence of a small perturbation of Barnard's Star similar to that reported by Sproul Observatory ten years ago has now been tentatively confirmed — although we still need some time to make a good quantitative comparison.

Photographic astrometry still makes a contribution to the search for extrasolar planets, and the entire field should not be written off because of a single and by now thoroughly understood difficulty.

R.S. Harrington
U. S. Naval Observatory
Washington, DC

behind the scenes | astronomy and the astronomers

This month we'd like you to share a bit of the thrill that astronomy gives astronomers. Our feature, "The Incredible Skies of Mauna Kea," comes to you courtesy of an amateur astronomer who spent two weeks observing in one of the best sites on Earth.

Then Martin Cohen evokes some of the the day-to-day reality of professional astronomy with "Do Supernovae Trigger Star Formation?" — and in doing so he gives us a glimpse into the mind of a modern scientist.

In our Forum section, a member of the Sidewalk Astronomers describes a magic night at the telescope during the group's latest public tour. If this inspires you to do something with your own telescope, learn how to patrol for supernovae from Mike Witkoski's story in Gazer's Gazette. And don't miss Berry Brunk's report on that astronomical affliction, light pollution, "Bright Lights Ahead."

Paul Burke's "Alt-Az Setting Circles" in Equipment Atlas offers you the opportunity to give your rusty algebra a workout. How? By crunching through coordinate conversion equations. It makes setting circles practical for Dobsonian telescopes!

Does everybody have a favorite galaxy? Mine happens to be NGC-4565 — and it's on the list in this month's Backyard Astronomer. For those of you without a telescope, Eye on the Sky brings you our monthly sky tour and Star Dome map.

By the way, over the years readers have asked us whether Star Dome is available separately. So "by popular demand," we've produced a big poster, The Starry Sky, with a map 22" in diameter. The poster is 24" x 36", color, on heavy stock, and features a short, illustrated history of telescopes. Everybody in the office has been snatching them — so we think we've got another winner.

Sincerely,
Richard Berry
Richard Berry
Editor

eye on the sky

four planets reach yearly peak

by Fred Schaaf

the wanderers

During April all four of the most prominent planets will be at their best for the year, with peak events concentrated in the early part of the month.

Venus is at greatest western elongation on April 1, and rises long before the beginning of twilight. This is usually the worst time of year for a morning elongation of Venus in the northern hemisphere, but since the planet's separation from the Sun is 46.46°, it will still be visible for several hours. The Morning Star will also average a magnitude of -3.4 this month and on the morning of April 17 is just 14′ of arc north of 3.8 magnitude Lambda (λ) Aquarii.

But Venus is not the only well-placed planet on April Fool's Day. If it is clear on that evening, take a look at **Mars**. The Red Planet will be only one day past opposition and will shine at -1.2 — its brightest since early 1976. Mars will be almost opposite the Sun that night, and will also be right beside Gamma (γ) Virginis in a very close conjunction. The planet will pass a mere 10.5′ of arc north of the 2.9 magnitude star during the afternoon, and the two remain close as darkness falls. The pair will be a fine and unusual naked-eye sight for observers with good sky conditions. If you are clouded out that evening, continue watching on subsequent nights as Mars retrogrades and comes closest to Earth on April 5 — only 0.64 AU away.

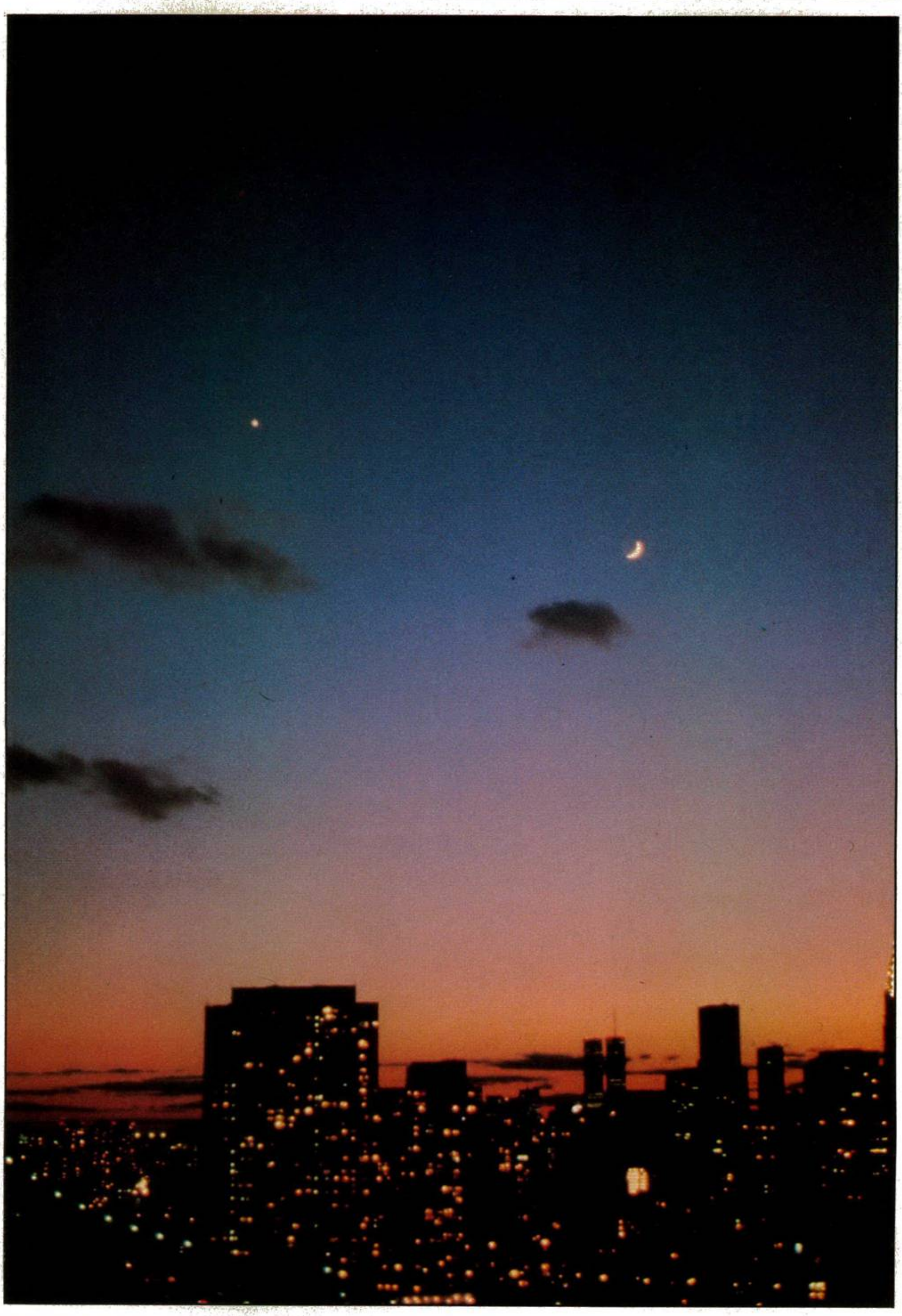
During April, Mars widens the gap between itself and the plodding planet that pursues it. That planet, **Saturn**, comes to opposition just 10 days after Mars. The ringed giant is closest to Earth on the evening of April 8 for viewers in North America, but is still 8.67 AUs distant. It shines steadily with a golden color and reaches its brightest on April 10 — magnitude +0.5. Compare its hue to that of Spica — the star to its southeast.

All of the planets, except **Mercury**, are well-placed at midmonth. Even 13th magnitude **Pluto** is at opposition on April 15. By the end of the month, Mercury begins to pull out from the Sun and will be visible low in the west.

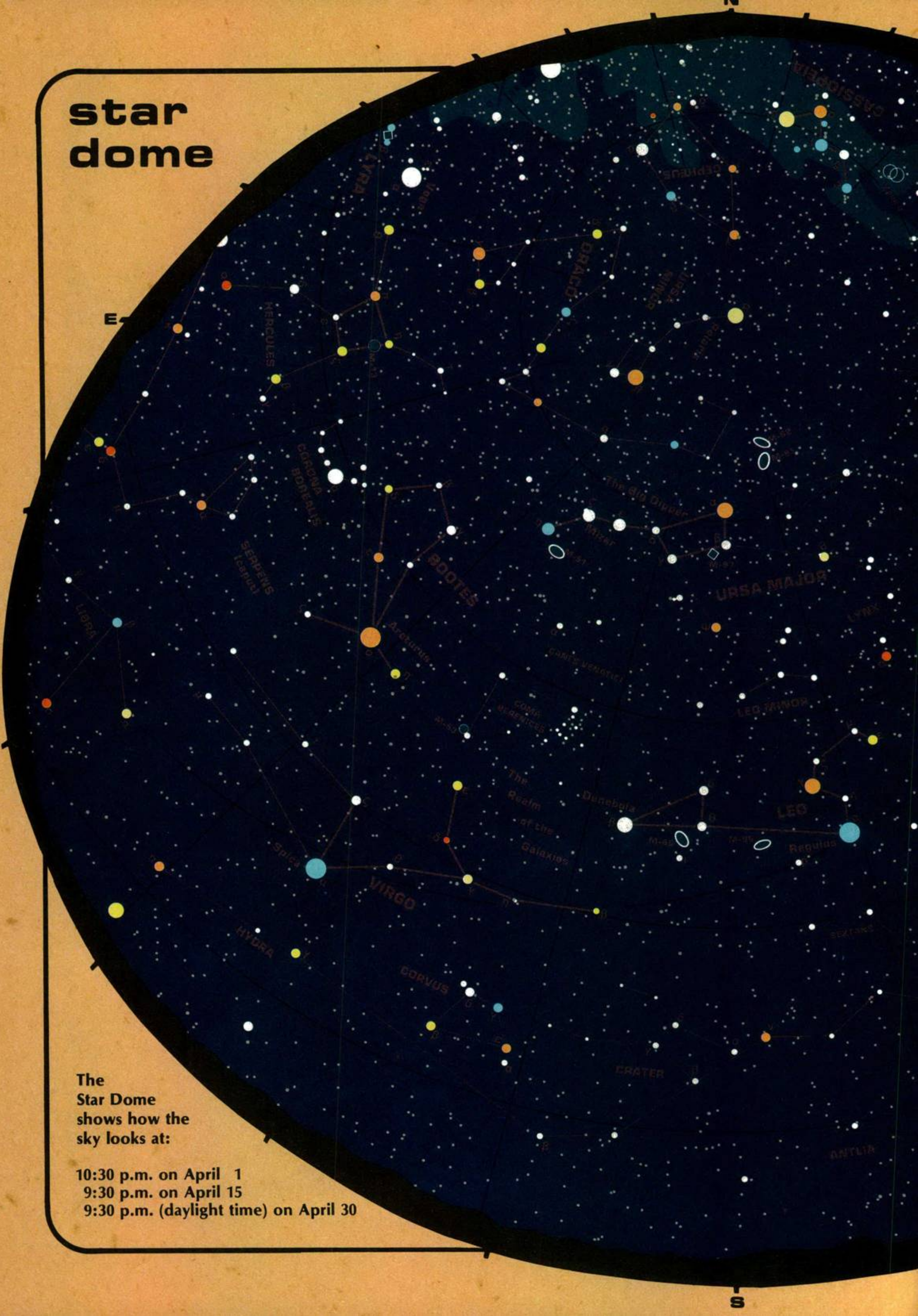
After you catch a brief glimpse of Mercury setting, turn back to the east and look below the triad of Mars, Saturn and Spica. Already ascended above the horizon mist is mighty **Jupiter**, reaching opposition on April 25. Jupiter is closest and brightest the next day when it is 4.43 AUs away — about twice as close as Saturn, but about six times farther from us than Mars. The giant planet shines at -2.0 magnitude on that night. Jupiter's magnitude occasionally deviates from predictions during times of unusual activity in its awesome atmosphere.

Late April is a good time to attempt a challenging feat of naked-eye observing — detecting jovian moons with unaided vision. The two prime candidates are Ganymede and Callisto. Ganymede will be brighter, but Callisto will be farther from the planet. Even at this relatively distant opposition, Ganymede will shine at 4th magnitude. Detecting these satellites with the naked eye is not simply a problem of light-gathering or resolving power; the glare of Jupiter will overwhelm these tiny dots and also distract your eye. You'll fare better if you look for the moons on a slightly hazy, and therefore glare-reducing, night. You must also be lucky enough to have one of these satellites near its greatest elongation from Jupiter. Try

Deepening twilight over Manhattan provides a colorful backdrop for the Moon and Venus. Alfred Krauss exposed Ektachrome 400 for 1/8 second through a 50mm f/2 lens. Despite the light pollution, one thing he treasures about New York is "roof-top" astronomy. At left is a -6 magnitude fireball that Hal Povenmire photographed during a 7-minute exposure through a 15mm lens.



star dome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The Big Dipper
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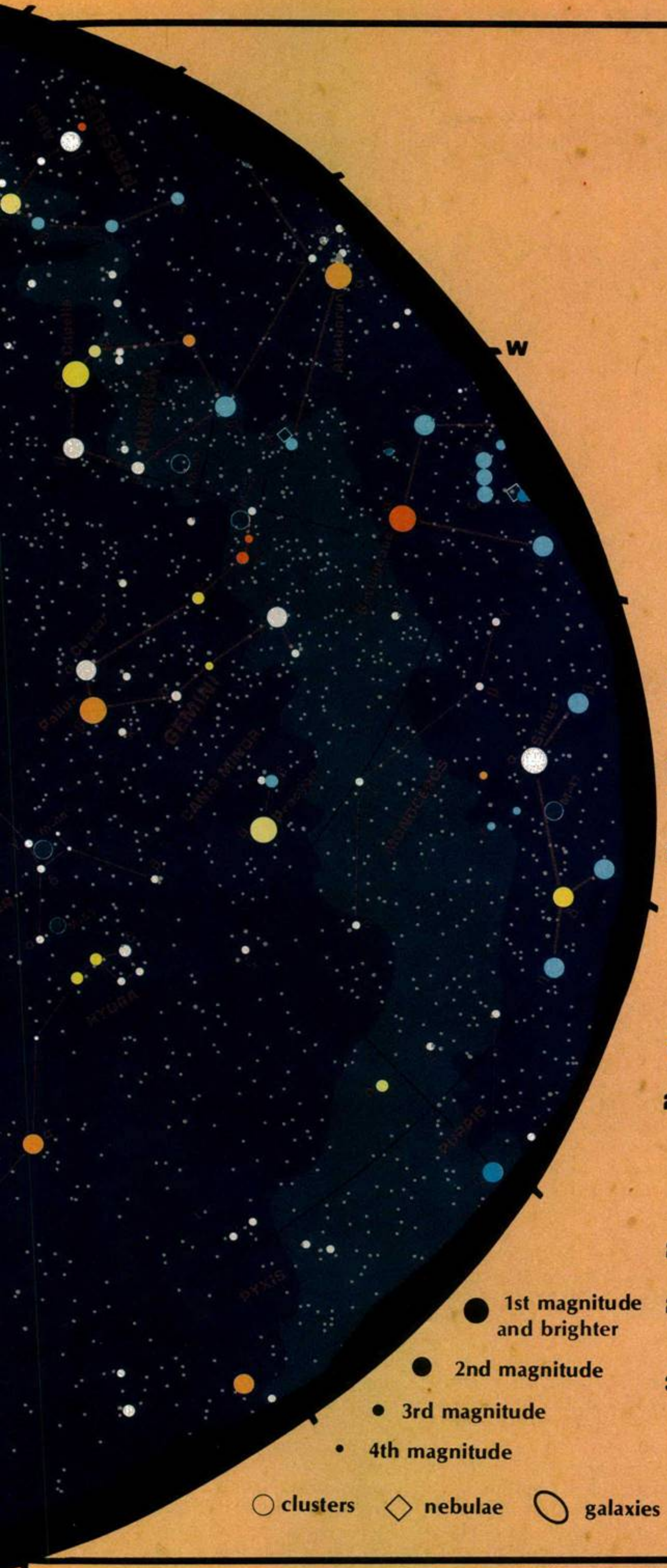
M-51
M-97
URSA MAJOR
LYNX
SERPENS (caput)
BOOTES
Arcturus
LIBRA
CANES VENATICI
COMA BERENICES
M-53
LEO MINOR
The Realm of the Galaxies
Denebola
LEO
M-65
M-66
Regulus
Spica
VIRGO
HYDRA
CORVUS
CRATER
SEXTANS
ANTLIA

The Star Dome shows how the sky looks at:

10:30 p.m. on April 1
9:30 p.m. on April 15
9:30 p.m. (daylight time) on April 30

april sky almanac


W
GEMINI
CANIS MINOR
MONOCEROS
HYDRA
PYXIS
Sirius
Procyon
Pollux
Castor
Aldebaran
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

1st	First Quarter Moon is at 12:08 a.m. EST. Venus is at greatest elongation west of the Sun.
5th	Mars is closest to Earth: 0.63513 AU — 59,039,000 miles.
7th	The Moon lies near Mars in the predawn sky.
8th	The Moon is Full at 5:18 a.m. EST as it passes north of Saturn. Later tonight, around 9 p.m. EST, Saturn will be at opposition.
9th	A waning gibbous Moon will lie to the east of Jupiter as it rises tonight.
11th	Mercury is at superior conjunction.
13th	The Moon is at apogee this evening: 251,449 miles away.
15th	Pluto is at opposition.
16th	Last Quarter Moon is at 7:42 a.m. EST.
20th	The Moon, a slender crescent, will lie below Venus in the predawn sky this morning. This evening you may be able to glimpse Mercury low in the west-northwest. During the next two weeks it will rise higher every evening.
21st	Mercury at perihelion — closest to Sun.
22nd	The annual Lyrid meteor shower reaches peak activity in the predawn hours today. Look for 5 to 10 meteors per hour coming from a region to the southwest of Vega.
23rd	The Moon is New at 3:29 p.m. EST.
25th	The Moon is at perigee this evening: 225,300 miles from Earth. Jupiter is at opposition.
30th	The Moon is at First Quarter at 8:07 a.m. EDT. Around 1 a.m. local daylight time, look for the Summer Triangle — Vega, Altair, and Deneb — rising in the northeast.

The Big Dipper is high overhead during April. Don Carney photographed this red aurora in the giant asterism using a 50mm f/1.8 lens and a 13-second exposure on push-processed Ektachrome 400. The dark skies of Sherman Pass, Washington, enabled him to capture many stars even with the short exposure.

not to prejudice your observations by checking their positions beforehand. Seeing these moons with the naked eye requires willingness to observe often as well as good eyesight.

the starry sky

The April sky is certainly dominated by planets, but it also holds a wealth of stellar attractions. **Orion**, **Taurus**, and **Sirius** all have their last nights of prominence on the verge of evening twilight; the **Big Dipper** swings high above the pole in the north during mid-evening, and **Leo** the lion crouches at the summit of an arch of zodiacal constellations that we can follow across the southern sky in a tour of the early spring heavens.

As darkness falls in early April, the **Pleiades** float just beyond the glow of twilight. For most American observers, the constellations **Taurus**, **Orion** and **Canis Major** now lie in a line roughly parallel to the western horizon. Another starry stratum above this one includes **Canis Minor** which features Procyon, **Gemini** and **Auriga**.

Although Taurus sinks from view during April, Gemini is prominent, with the figures of the Twins standing nearly upright in the west. Castor marks the head of the northern Twin, and Pollux the southern. Their feet are firmly planted on the luminous band of the Milky Way. Unfortunately, you won't have much time to see this band because it sets early and leaves the sky almost Milky Way-less for North American observers.

Moving eastward on the zodiac after Gemini, we come to **Cancer** the crab, now high in the southwest. If you have binoculars, check out the mysterious glow in the midst of the Crab — M-44, the **Beehive** or Praesepe cluster. The total magnitude of this cluster is 3.7 — brighter than all the stars of dim Cancer except for **Beta** (β) **Cancri**. The brightest star in the Beehive itself is magnitude 6.3, but even in the darkest skies it seems to be lost to the naked eye amidst the glow of its dozens of fainter cluster members.

Just south of Cancer is the head of **Hydra** the sea serpent, connected by a scattering of faint stars to the slightly ruddy second magnitude star **Alphard** — "the lonely one." Alphard marks the heart of this long stellar serpent and the name is fitting because this area is indeed vacant.

Not as barren is the region to the northeast of Alphard. There bends the **Sickle**, an asterism that contains second magnitude **Algieba** and first magnitude **Regulus**. Just as Alphard is Hydra's heart and Antares is the heart of the summertime Scorpion, Regulus marks the heart of Leo — not a ghastly beast, though, but the noble Lion. The Sickle outlines Leo's massive head, mane, and chest, with Regulus at the end of the handle. The dim star **Omicron** (o) **Leonis** or Subra indicates the forepaws of Leo, but his hindquarters are distinguished more prominently by a right triangle of bright stars.

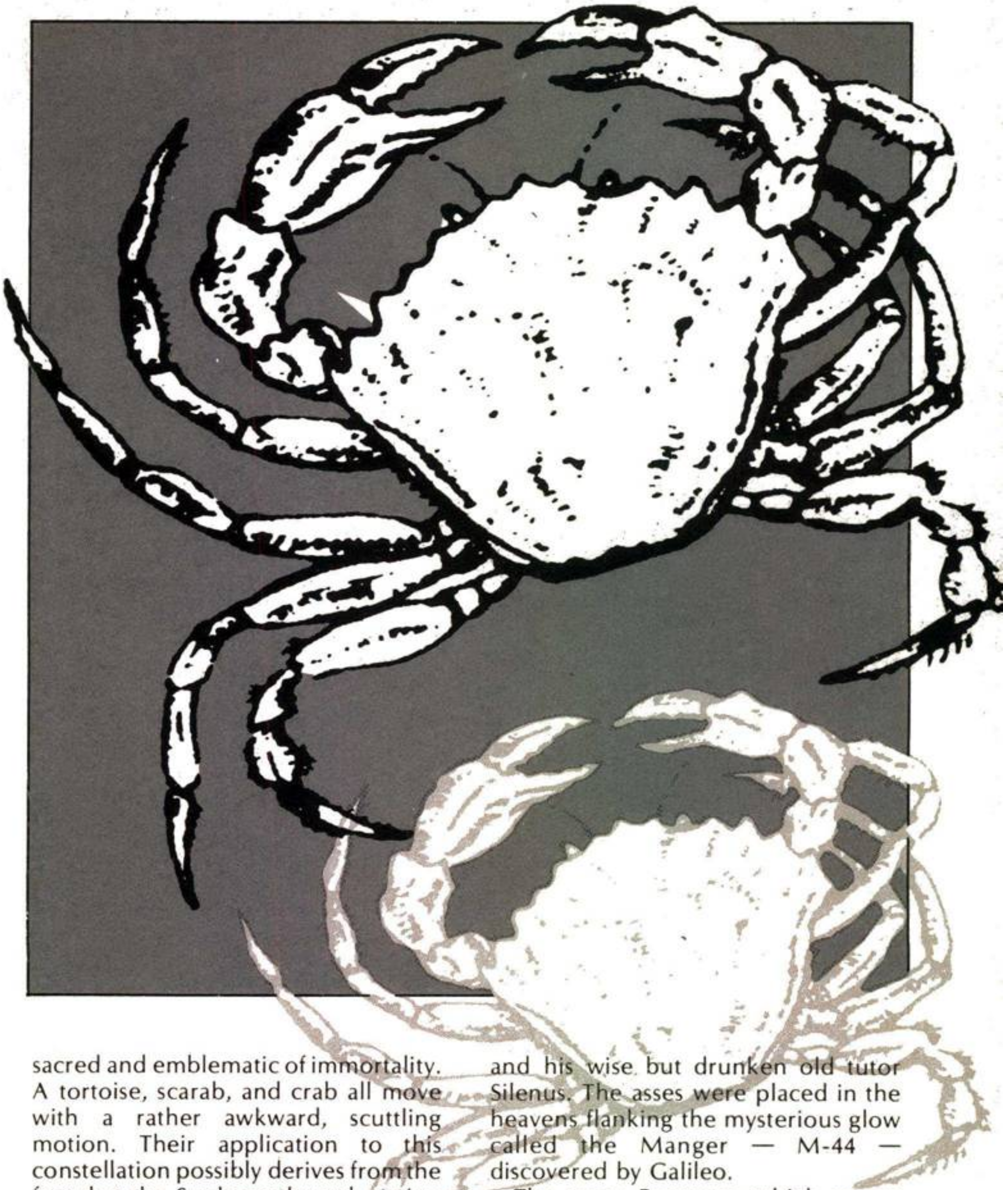
Leo is certainly famous, but high in the north across the zenith from him is the most famous of all star patterns — **The Big Dipper**. Of the Big Dipper's seven major stars, only the point of light that connects its bowl and handle is fainter than second magnitude. Four of them are magnitude 2.0 or brighter.

This constellation is not only beautiful, it is also a useful locating asterism. The famous Pointers, **Dubhe** and **Merak**, on the outward part of the bowl lead to the North Star. And here we also find the famous "arc to

Arcturus" — follow the curve of the handle outward to that brilliant orange star ascending in the northeast on April evenings. If we draw a line through the Pointers away from the Pole, we find Leo. Many other courses have been devised using the Big Dipper. See if you can invent some for yourself. The object is not just to help you find other constellations, but also to give you a better aesthetic sense of the patterns and relations between these groups.

If you are admiring the Big Dipper in a dark sky, trace the form of the far larger constellation of **Ursa Major**, the great bear, now hanging upside down to an observer looking north. Three feet of the vast Bear are marked by three pairs of stars — the medieval Arabs' "Three Leaps of the Gazelle." These three "star-pairs" are now arranged in little leaps across the zenith for North American observers.

Down in the vicinity of Saturn and Mars shines **Spica**, the brightest star in **Virgo** the virgin. **Vega** has just appeared above the northeastern horizon, even though the summer it heralds is still far off.



skylore

If it were not part of the zodiac, the area between Gemini and Leo might have gone unnoticed in ancient times — except as a gap! Instead, Cancer the crab has a long and rich history in legends.

In classical antiquity, Cancer and its counterpart Capricornus contained the positions of the Sun at the solstices. Even today we have relics of this — the names of the tropic lines of latitude where the Sun is overhead at the beginning of winter and summer.

The early Platonists thought Cancer and Capricornus were the entry-way and exit, respectively, for the souls of men: Cancer was the Gate of Men through which souls descended to Earth; Capricornus was the Gate of the Gods through which these spirits ascended to heaven. Still another legend concerning these two constellations was a belief that the world would be consumed in flame when all the planets met in Capricornus — or drowned in a flood when they all came together in Cancer.

We don't know how long this configuration of stars has been called a crab but on the famous Denderah zodiac of Egypt, a crab appears above Leo (where we now have Leo Minor). That large stone chart was based on the constellation's positions of 700 B.C., quite late in the history of Egypt. Cancer seems to have been a tortoise in both Babylonia and in early Egypt around 4000 B.C. Two thousand years later, the constellation is identified in Egyptian records as a scarab beetle — sacred and emblematic of immortality. A tortoise, scarab, and crab all move with a rather awkward, scuttling motion. Their application to this constellation possibly derives from the fact that the Sun's northward motion slows and appears hesitant around the time of the summer solstice — before it begins to sidle with a crablike movement southward again.

One Greek myth tells us that this crab pinched the toe of Hercules when the hero was fighting the Lernean Hydra. The legendary strongman crushed the crab beneath his foot and went on to vanquish the Hydra. But this made Hera angry and she rewarded both Hydra and Cancer with places in the heavens near each other — and also near a third foe of Hercules, for Leo is often regarded as the Nemean Lion.

Among the Greeks the stars Gamma and Delta Cancri were also known as the Aselli, or asses. Gamma is Asellus Borealis — the Northern Ass; Delta is Asellus Australis — the Southern Ass. A Greek myth tells that these asses aided the gods by adding their brays to the gods' shouts to help terrify a group of fierce giants who were coming to avenge their brothers, the Titans, by overthrowing the Olympians. These animals may be the asses of Dionysius and his wise but drunken old tutor Silenus. The asses were placed in the heavens flanking the mysterious glow called the Manger — M-44 — discovered by Galileo.

The name Praesepe, which means "Manger," was probably given to the cluster after the naming of the Aselli. Not surprisingly, the Greek figures were associated with the alleged nativity of Jesus by Christian stargazers. The cluster was seen as a nebula or "little cloud" by the ancient Greeks. In fact, it was the only universally recognized "nebula" before the invention of the telescope. Although the Double Cluster is equally bright, and in a prominent constellation, it was not known to many early skywatchers simply because it is not in the zodiac.

The Greeks also used Praesepe as a weather forecaster. It was a sign of coming rain if the Aselli looked unaltered but the Manger looked "murky." An extended object like M-44 would be affected more noticeably by thin cirrus clouds or the increased humidity preceding a rain system, so these early meteorologists may have been on the right track. Why not test this ancient piece of astronomical weather-wisdom on the Beehive tonight?

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Remember 10 or 15 years ago when you used to pack up the scope, load it into the car, and meet the rest of the club at Ingersoll's farm for the monthly star party? And how about those skies! Only 20 minutes from town and they seemed as dark as could be. But as the months and years passed, the contrast gradually vanished, and the Milky Way disappeared from view. When the brightening in the sky got too bad you looked for alternate observing sites, but had to travel farther and farther from town to find those dark skies so important for stargazing.

For a time, the new site generated a lot of excitement and discussion among club members. Everyone marveled at the darkness of the skies and how easy it was to locate deep-sky objects. Nearly all of us saw our favorite Messiers as we hadn't for a long time, and they brought to mind literary passages from famous nineteenth century observers. Those members who were good at photography couldn't believe their results. Some of them even stopped using their red filters! But after a while the filters found their way back onto the lenses and complaints increased. Once again, light pollution had caught up with us and we had to find another place for our star parties.

This scenario is not fiction. Astronomy clubs across the country are acting it out. In fact, the problem has become so widespread that the effects of man-made light threaten major professional observatories. Too much light escapes into the sky — doing too little good on the roads and highways it was meant to illuminate. The problem is not easy to correct. Over the past three decades our society has encouraged the growth of outdoor lighting and the belief that more light was good. But we've finally reached a point when lights are added for no apparent reason. Sure, streetlights save lives, but what about the 40% waste from each and every light that simply scatters into the atmosphere? How is that helping the motorist or pedestrian? It isn't. And since this scattered light doesn't do the job we intended it for, it *is* a waste of money. That's the real clincher — especially in these belt-tightening economic times.

In 1972 the city of Tucson, Arizona, adopted the first ordinance concerning outdoor lighting and the effects of light pollution. It is not surprising that Tucson was first. Kitt Peak National Observatory, home of many of the most active telescopes in the world, lies just outside Tucson. The astronomers there had been keeping a wary eye on the growing city since 1959, and were finally convinced that something had to be done to stop the insidious effects of urban growth on their research. That original ordinance required the use of downward shields and filters on many of the lights in Tucson. It was a big step in the right direction, and it set an example for other cities.

The success in Tucson is a product of two different groups working together: astronomers and the city's lighting engineers. Getting these two groups together is the first step in solving the problem. Few amateur astronomers realize the effects of light pollution — and these are people who are very interested in the night sky. So how can we expect engineers, or other astronomical laymen, to understand the problem? Unless you approach them very carefully with your data and information, they are liable to just laugh at you, scoffing the whole time about the group of nuts lobbying against light. After

Background photos of Tucson in 1950, 1972, and 1980 courtesy Kitt Peak National Observatory.

BRIGHT LIGHTS AHEAD!

all, doesn't everyone want more light at night?

This kind of mentality is one hurdle that light pollution committees must overcome. They have to change the average citizen's outlook on the problem before any corrective action starts. It's just simple human nature. If a problem doesn't affect you individually, you tend to overlook it.

In 1973, following the Tucson decision, Merle Walker of Lick Observatory in California did a study of light pollution. There the problem had been known since the early 1930s, when astronomers decided to place the 200-inch at the remote Mount Palomar site instead of at Mt. Wilson — which overlooks the sprawl of Los Angeles. While only one city affected Kitt Peak, the California problem was harder to correct — several spreading metropolitan areas encroached on the largest telescopes in the world. Walker concluded that even with "cooperation from state and local officials, it is unlikely that the sites already seriously affected by light pollution can be substantially improved. Even with the best possible control, conditions will continue to deteriorate slowly, because of the increase in population density. This will be a potentially serious problem in all countries as industrialization and standards of living increase. Therefore, to protect the world's best sites for optical astronomical observations, it is essential to begin now — before pollution problems develop."

More recently, Sandra Faber has crusaded against the effects of California light pollution on Lick Observatory. The *Wall Street Journal* interviewed her in 1979 about the problems the city of San Jose presented to astronomers:

"There's no question that San Jose has seriously affected our scientific work at Lick," Mrs. Faber said. "The night sky is four times brighter than normal."

The ironic part of this problem is that there is a solution that could satisfy all opposing groups — the government, the public, and the astronomers. It concerns the types of lights used. Back in the sixties, as towns and cities grew, unencumbered by limited budgets, engineers installed mercury vapor lights as the main type of outdoor lighting. But engineers today have devised newer, more efficient types of lighting — namely sodium vapor.

Sodium vapor lights are easy to identify — they're the orangish lights sprouting up in many American cities. Lighting engineers developed them because they are 50% more efficient than mercury vapor — they use half as much electricity and cost much less to run. Why the problem then? If they have a light that is cheaper to operate, why don't they simply replace the mercury vapor lamps with sodium. The answer to that question is complex.

City governments defy change unless they are forced. Why disturb the status quo if there are no complaints? There are so many other vital programs to attend to that converting all the streetlights in a city from wasteful to efficient models isn't a high priority item. Government needs a catalyst — such as an astronomical lobbying group or tight economic times to set it in motion. Today, city electric bills are higher, and public works buyers are looking for ways to cut costs. Programs of retrofitting mercury vapor lights with the newer sodium varieties have begun. This is great for astronomers except for one thing — there are two types of sodium lights, high pressure (HPS) and low pressure (LPS).

Mercury and Venus set in the sky behind a shopping center in Pensacola, Florida, while a mercury vapor light illuminates the foreground. Photo by Merry Wooten.

High pressure sodium emits a pinkish light over the entire yellow-orange-red region of the spectrum. It is very hard to remove this light with filters — almost impossible, actually. However, low pressure sodium, while as bright and as cheap to operate as high pressure, emits light in only a very narrow wavelength — yellow — that is easy to filter out. The new problem facing astronomers is how to persuade city governments to install the low pressure type. It's a new twist to the same old problem.

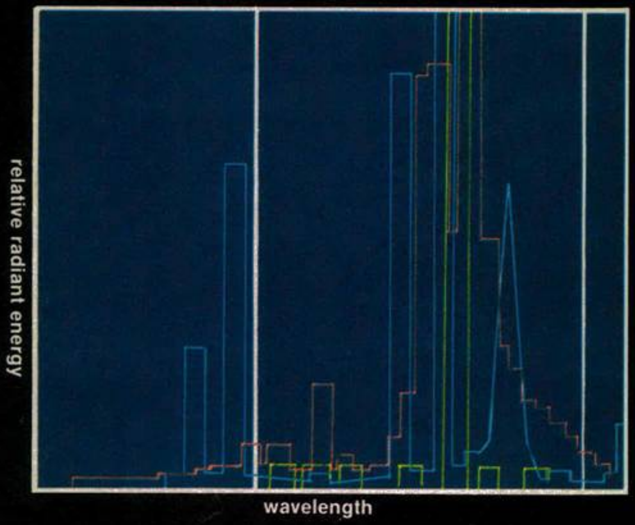
Although it is generally agreed that sodium vapor is the way to go, there is some difference of opinion over which type is better. The city of San Jose conducted several surveys and studies regarding the Police Department's and the public's impressions of the new lights. Complaints usually center around the differing color of the lights and the degree of nighttime visibility.

According to Faber, if San Jose installed nothing but high pressure sodium in place of mercury vapor, the light pollution problem would be magnified. Mercury vapor lights are easy to filter out. "Within a very short time the red and yellow continuum of the spectrum due to man-made skyglow will jump by an average of 35% more pollution," Faber said. "We very much fear that the widespread use of high pressure sodium streetlights in the Santa Clara Valley would gravely impair Lick Observatory's ability to study faint stars and galaxies. In contrast, the use of low pressure sodium in the Valley would actually improve conditions, since the six separate emission lines of mercury vapor would be replaced by the two narrow lines of LPS."

As a result of these studies, the city of San Jose — in a 1978 Report entitled *Sodium Vapor Luminaire Conversion* — stated that conversion to a combination of high and low pressure sodium vapor lighting would save the city more than $4 million. The Public Works Department suggested that using both HPS and LPS in various areas around the city would be most effective in reducing the overall lighting costs. They specifically requested that no HPS lights be used in a nine-mile radius around Lick Observatory, but that HPS lights be used in some areas away from the observatory where the colors of the streetlights would not be confused with yellow traffic signals. It seemed a compromise that everyone could live with.

Since that study was completed, several other conclusions have come to light. Faber points out that: "Shielding HPS luminaires (with downward reflectors) will not significantly reduce their contribution to man-made skyglow or lessen their impact on astronomical observations. The amount of man-made sky glow over Lick Observatory is four times greater than a naturally dark site. The light of streetlights alone constitutes 35% of this man-made component. Since light from streetlights cannot be reduced by shielding, control over the type of light source is the only remaining option to reduce the pollution. Thus, from an astronomical standpoint, a monochromatic light source such as low pressure sodium is the only viable remedy."

Of course, either type of sodium light significantly reduces the electric bill from streetlights. But since HPS lights are so hard to filter out of the sky, astronomers prefer replacing the old mercury vapor lamps with low pressure sodium. In San Jose's Public Works Department report, city engineers concluded



This chart shows the emission lines of three types of lighting. LPS is yellow, HPS is orange, and mercury vapor is greenish.

that the best conversion of existing mercury vapor lamps would be "primarily to an LPS lighting system save for minor arterial streets where HPS lights would be used, as long as they were outside the nine-mile radius surrounding Lick Observatory. An LPS system will cost 20% less to install than an HPS one and will also have lower operating and maintenance costs. It will take nine years for the entire system to pay for itself at a conversion cost of $4.4 million. The yearly savings will approach $1 million. The dispute concerning the color of LPS lights has been researched and there is little problem with it. Both LPS and HPS will aid law enforcement and the color rendition under LPS will present no major problem to public safety."

In the conclusion of their report, the city council stated that, "the choice to convert city streetlights to primarily an LPS lighting system becomes tantamount if Lick Observatory is to be considered a community resource of value, worthy of any effort to maintain its function." Chalk up another victory for light pollution opponents and the residents of San Jose.

California isn't the only state whose citizens have realized the deleterious effects of too much stray light. All across the country municipalities have begun to study and even convert to more efficient forms of streetlighting, wisely following the precedents laid down by Tucson and San Jose.

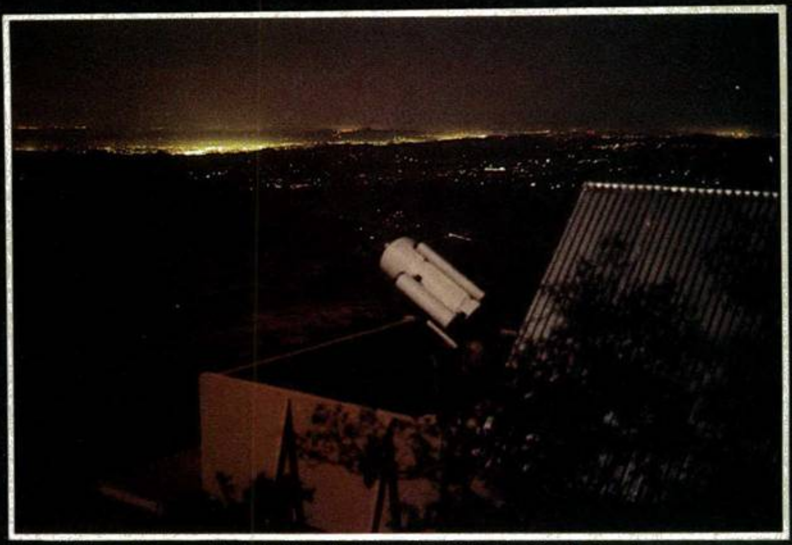
James R. McCormick of the Cleveland (Ohio) Electrical Power Company became interested in the problems of light pollution, or "light trespass" as illumination engineers call it, when Case Western Reserve University moved its Warner and Swasey Observatory to Kitt Peak. Light pollution was among the reasons for the move. McCormick said, "I was not really aware that the problem had severely impacted Cleveland until the Warner and Swasey move; then I started reading up on it. It concerned me that we had lost the observatory. It would be a tragedy to lose ground-based observatories, but this is a *very* serious threat. We need to attack the problem on a case by case basis."

McCormick went on to say that, "the two sides (astronomers and engineers) were not talking to each other — that really bothered me. I think an exchange of information between astronomers and engineers is the first step in solving the problem. If the two groups would talk more and make their research available to each other, then they could get the problem out in the open."

Both sides do look at it from different perspectives, and tend to be suspicious of each other's motives. But both sides also stand to benefit.

Now both large utilities in Cleveland are trying to find ways of directing local lighting to keep conditions as good as possible for astronomers and non-astronomers. "We looked at LPS," McCormick said, "but most lighting engineers don't like it — it doesn't provide the needs lighting is supposed to. However, there has been an overwhelming favorable reaction for HPS, (from an engineering standpoint) although we know that it is harder to filter out of the sky."

Now that Warner and Swasey Observatory is no longer in Cleveland, the choice between HPS and LPS is not as critical. Both are similar in costs to install and operate, and with no astronomical groups taking a stand for LPS it appears that the city of Cleveland will



The lights of Escondido, California, glow brightly behind Alfred Lilge's backyard observatory.

install a majority of HPS lighting to decrease its electric bill.

At Franklin and Marshall College in Lancaster, Pennsylvania, Dr. Dennis Dawson has another story to tell. When he worked at the Wesleyan University Observatory during 1980 they had a tremendous problem with the campus lights. Background light was so bad that astronomers could not find the guide stars they used in the parallax measurements they have become famous for. "There were large parking lots near the observatory as well as malls and other shopping centers. When these lights were not on, the sky brightness fell by a factor of two," Dawson said.

Art Upgren, an associate professor of astronomy at Wesleyan said, "we have a very severe lighting problem — worse than anywhere else." The need for maximum illumination at night to protect the campus coeds resulted in the indiscriminate use of lights. When Upgren approached the administration with his complaint — that the parallax program with the university's 24-inch Cassegrain was being damaged by light pollution — he suddenly found himself involved in the whole decision making process.

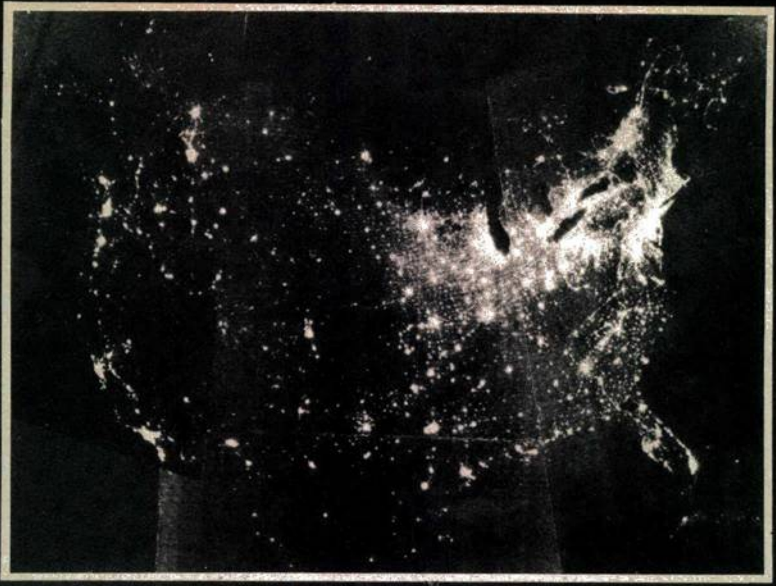
"All we wanted was input into the process so the lighting people would know our side," Upgren said, "but it became a long, slow educational process of convincing the university that our problem was real. They seemed to be in favor of a lot of night lighting, because of a number of assaults on students." Upgren said that he inspected the areas of many of the assaults and nearly all occurred very close to a light.

In 1980 Upgren became involved with a research support group called EARTHWATCH to study and analyze the degree of light pollution with a very sensitive photometer designed by Dawson. Upgren enlisted volunteers in many U.S. and foreign cities to take readings on the amount of light at night.

Outdoor lighting is the fastest growing user of electricity. While overall energy consumption increased 25% over the past decade, the use of electricity for outdoor lighting went up 300% — twelve times faster. When Upgren took measurements at Wesleyan, he found that the sky at the zenith outside the observatory was 20 times brighter than a natural dark sky. With this data in hand he influenced the university administration more effectively. "Through just plain politics I have been able to get our university to curb its excess use of lights," Upgren said. "First we had to make a big splash so they would realize that our research was being affected."

Upgren believes the paramount problem in combating light pollution is that the general public does not take it seriously. "Light pollution is not yet perceived as a major problem — only as an inconvenience to stargazers. It appears to be just one more social cause taking its minor place amid the rising clamor of partisans of other social causes." Upgren continued by saying, "this will be a problem until the national awareness passes the critical point like other problems and becomes widely recognized."

It's easy to understand the enormity of this problem when we must understand that most people still want more light at night. In Milwaukee, John Asztalos of the Milwaukee Astronomical Society



From orbit, the night face of North America looks like this — a vivid testimonial to the amount of wasted light shining into the atmosphere.

related a story of the club's efforts to convince the nearby town of New Berlin to look ahead to the day when lighting might be a problem. The club's observatory was close to numerous lights, so the MAS light pollution committee approached the town council with their information. "The city council was sympathetic," Asztalos said, "but they weren't willing to do anything about it. right now they are trying to persuade industry to move into their city, and they don't see any advantage in curbing the growth of lights to help out an astronomy club." Many astronomy clubs throughout the nation have experienced similar defeats. Others have been luckier.

In Virginia, June LoGuirato, a member of the Astronomical League and the Richmond Astronomical Society, started to lobby the state legislature for the passage of a light pollution bill similar to the Tucson ordinance. Two public hearings were held with no opposition speakers, but the bill was still amended five times before it was signed into law on July 1, 1980. And Virginia is only the third state to pass such legislation.

In view of situations like this, the Astronomical League formed a nationwide light pollution committee to help local astronomy clubs with their problems of presenting their cases in the most effective way.

Gerry Sherlin, the AL's Light Pollution Committee Chairman, lives in Alamogordo, New Mexico, and is a solar astronomer at Sacramento Peak Observatory. He said the problem is so individualized for each particular area that general guidelines don't apply. "In Alamogordo, for instance, we have very little glow and it doesn't affect our photometric work," Sherlin said, "but California is a disaster area. In fact, we're really not bothered by light pollution here in New Mexico. The rural skies of Nebraska are also very good," he said.

"I think that composite pictures of the skies around observatories showing the growth of the city out toward the installation would be something people could relate to. I think they would be interested in seeing the growth of lighting over a period of many years."

This is the state of affairs today. Local light pollution ordinances are difficult to pass — even when you have overwhelming evidence to prove that you can save the municipality money in the future. Bright lighting is something we have come to expect, and we have many years of perceptions to unravel before we can demonstrate that it may not be in everyone's best interests. Although several reports have demonstrated that additional lighting has no impact on reducing crime, many people, even lawmakers, still cling to this misconception.

Astronomers don't advocate turning off all lights at night and plunging the world into darkness. But they do want to demonstrate options. Lighting engineers can choose efficient forms of lighting that save money and protect the citizenry at the same time they preserve good astronomical skies. There are solutions that can please everyone, but we need open discussion and a willingness to see the problem from all sides.

— *Berry Brunk*

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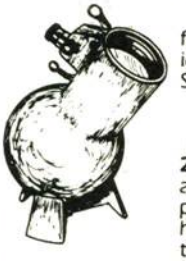

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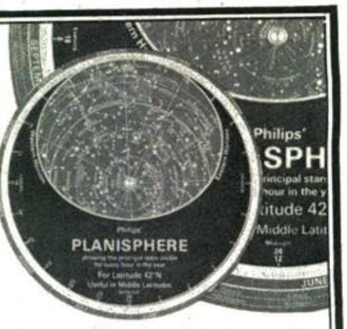

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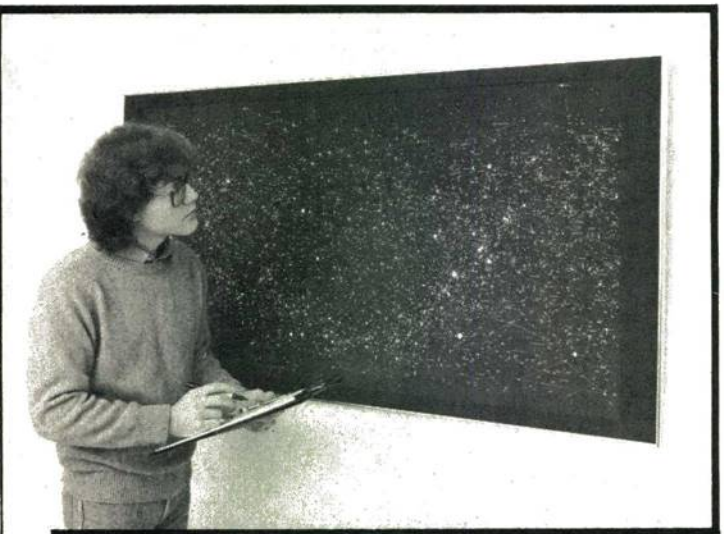

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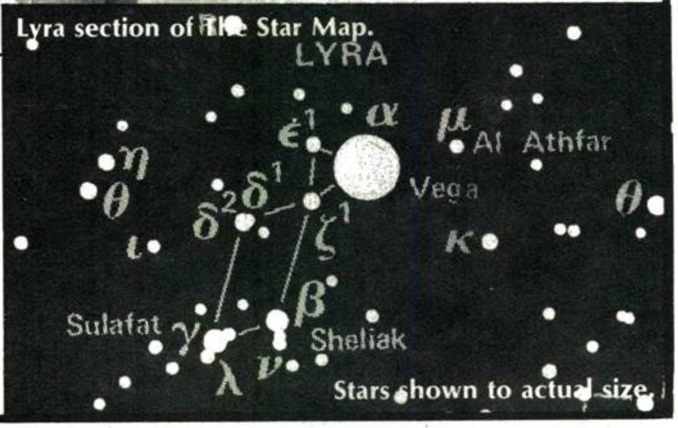
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LIGHT BAFFLES IN A CASSEGRAIN TELESCOPE

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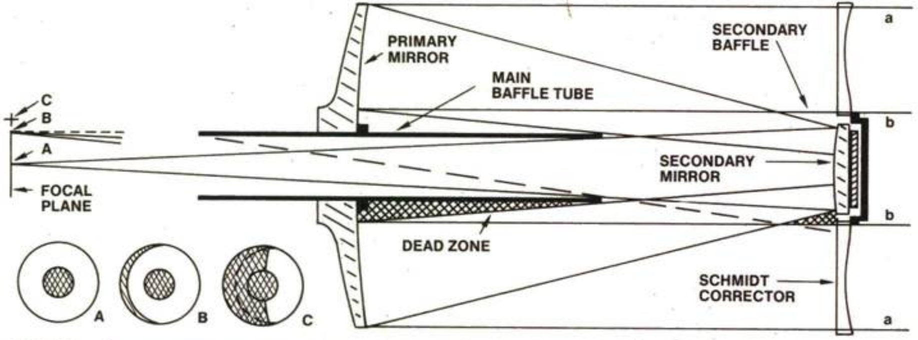

FIGURE 1.—Scale drawing of the Celestron 8 mirror and baffle tube arrangement. The cross-hatched areas of the drawing show where light baffles may be placed without interfering with on-axis rays. The circles at the lower left show the shadowing caused by the baffle tubes off-axis. (A) on axis, (B) corner of 35mm format, (C) 0.69° off axis.

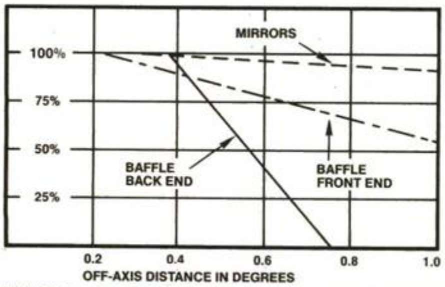

FIGURE 2.—Computed light fall-off caused by the primary and secondary mirrors combined. (a) the forward end of the primary baffle tube, (b) the rear end of the baffle tube.

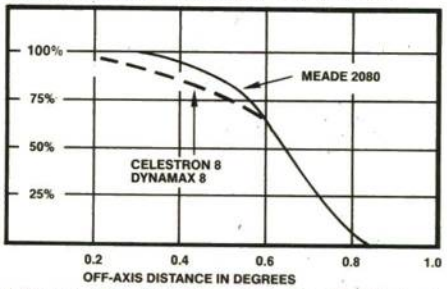

FIGURE 3.—The actual off-axis illumination of a Celestron 8, Dynamax 8 and a Meade 2080. Note that the Celestron 8 and the Dynamax were so close that they were plotted together. Also, note that the drop-off of all three systems confirms that the baffle tubes introduce the only measurable off-axis light drop-off of these systems.

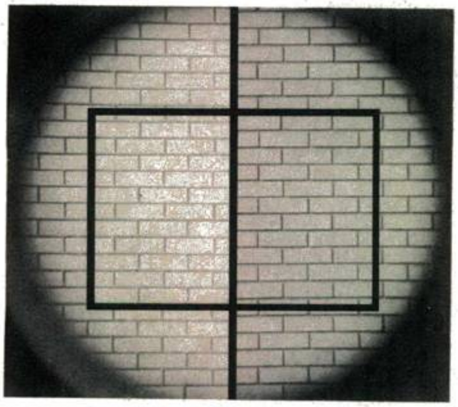

FIGURE 4.—Low-contrast field comparison shots on 6 x 6 cm format taken with the Meade 2080 (left) and the Celestron 8 (right). Note that there is no detectable drop-off in either system within the 35mm format (overdrawn). The stray light outer ring of the Meade photo was apparently caused by inadequate opaquing of the baffle tubes.

Considerable confusion has been stirred up among would-be telescope purchasers by some advertising relative to the effect of off-axis illumination that can be achieved by using an oversize primary mirror in an 8-inch Schmidt-Cassegrain telescope. We respectively suggest that a computation be made of the actual amount by which the outer rays are deflected outward. We have and it is 0.008 inch on the primary mirror. The 0.060 inch by which the Celestron mirror is oversize fully catches all of these outer rays. What our competitors overlook in their advertising is that the light fall-off at the edge of the field caused by either the primary or secondary mirror is insignificant compared to that caused by the baffle tube system.

The Celestron 8 was thoroughly engineered for optimum performance in regard to off-axis illumination and light baffling. The baffle system prevents any unfocused light that may bypass the secondary from arriving at the focal plane. With the exception of certain minor modifications, competitive Schmidt-Cassegrain telescopes are substantially the same. Any improvement brought about by these minor modifications is questionable.

LIGHT BAFFLES FOR CASSEGRAIN TELESCOPES

Figure 1 is a scale drawing of the mirror placement and baffle tube arrangement of the Celestron 8. The variables at the designer's disposal in arriving at an optimum design are: 1. Primary and secondary mirror sizes; 2. Diameter and length of the primary baffle tube; 3. Diameter and length of the secondary baffle tube. The first step in designing the light baffle system for a Cassegrain telescope is to make a scale drawing of the mirror placement of the proposed system. Two sets of lines representing the outermost rays (a) and innermost rays (b) are drawn through the system. It will be noted that a dead space (no light rays present) is defined by these sets of lines. This is shown cross-hatched in Figure 1. It is in this space that the light baffles may be placed. Since it is only necessary that unfocused light be prevented from arriving at the focal plane by these baffle tubes, the baffles need not extend to the maximum available space. Having established a proposed light baffle system, the off-axis performance for a given set of mirror sizes may be readily evaluated.

Figure 2 is a graph which shows the effect on off-axis illumination of each of the several factors which influence off-axis illumination of the Celestron 8. It will be noted from this figure that the light drop-off caused by the primary or secondary mirror is negligible when compared to that of the baffle system.

The inside diameter of the primary baffle of the Meade 2080 and the Dynamax 8 is the same as in the Celestron 8 (1.5 inches). Therefore, the abrupt light cut-off as caused by the rear end of the baffle tube is the same in all three systems. In the Dynamax 8, the primary baffle is ½-inch longer than the C8. Therefore its light fall-off would be slightly greater than the Celestron 8. In the Meade 2080, the primary baffle is 1.5 inches shorter, thereby increasing the 100% illumination 7½ arc minutes further off-axis than either the Celestron 8 or the Dynamax 8. This, however, results in stray light being present at the corner 0.2 inch of a 35mm format. This coupled with the inadequate opaquing of the baffle tube itself resulted in the Meade 2080 evaluated having considerably reduced contrast when used as a telephoto lens or for daytime terrestrial observing.

Celestron 8, Serial No. 811417; Meade 2080, Serial No. 800544; and Dynamax 8, Serial No. 710176, were each set up in a collimator and tested in regard to off-axis illumination. A sensitive photometer was used to make these measurements. Figure 3 is a plot of the test data taken. We leave it to you to conclude whether or not either the Meade or Criterion oversize mirror gives the superior off-axis illumination which they claimed.

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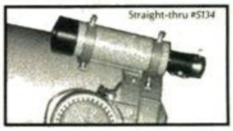

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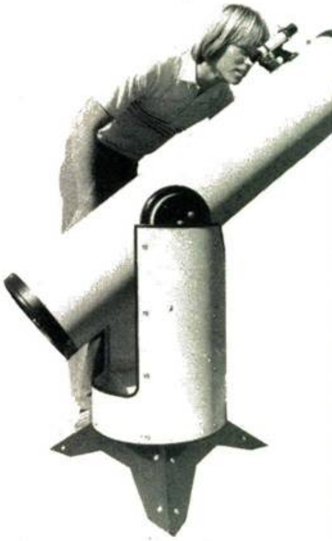

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searching for supernovae

gazer's gazette

by F. Michael Witkoski

Perhaps the most unpredictable event in all the heavens is the appearance of a supernova, the explosive death of a massive star. Surging up from obscurity, the flare of light that marks this cataclysmic event usually remains a luminous beacon for months or years until it fades slowly to invisibility.

On average, one supernova should occur in a galaxy such as ours every few hundred years. The most recent was in 1604, just before the telescope was invented. Others appeared in 1006, 1054, and 1572, and several additional suspects from medieval and early modern times are also on record. We seem to be overdue for another — though it's perfectly possible we've missed one or more that occurred on the opposite side of the Galaxy and were hidden from sight by the Milky Way's dense clouds of dusty gas.

Fortunately, astronomers don't have to count exclusively on our own Galaxy's supernovae — if they did, our knowledge of them would be pretty scant. Instead, they rely on studies of the supernovae that occur in other galaxies. Though great distances separate us, these explosions happen fairly frequently, and sophisticated modern instruments can discern their workings.

M-83 by Roger Sliva

The earliest extragalactic supernova on record occurred in August 1885 in the Great Galaxy in Andromeda, M-31. Astronomers at the time thought that M-31 was relatively nearby, so they designated the bright star as they would have an ordinary nova: S Andromedae. Just visible to the naked eye at its maximum brightness, this star peaked at magnitude 5.4 — only two magnitudes fainter than M-31 itself.

M-64 by Martin Germano

But M-31 isn't nearby; it's a gigantic spiral assemblage of stars somewhat larger than our own Galaxy swirling about some 2 million light-years away. It wasn't until years later when astronomers measured M-31's actual distance that they recognized the titanic amount of energy S Andromedae had released. Since 1885, about 500 additional extragalactic supernovae have been discovered, many of them as bright or brighter than their host galaxies.

Since many backyard observers today have scopes of 8 or 10-inches in aperture, galaxy chasing is no longer exclusively the sport of the professional. And if galaxies are within the grasp of these instruments, so are their supernovae. Just think — to see a supernova in your lifetime, you don't have to wait for The Big One — you just have to do some systematic patrolling.

Of course, it's impossible for any one individual to monitor the entire sky — or, for that matter, even all the galaxies your scope can theoretically reach — but you can establish a sensible approach. First, find a sequence of galaxies to examine visually or photographically during a night's observing. Then follow these up in subsequent sessions and, as the seasons roll the sky westward, add new galaxies farther to the east to replace those lost to the Sun in the west.

NGC-253 by Dale Lightfoot

But how do you do it? And what should you look for? In your telescope, an extragalactic supernova will look just like an ordinary star — a tiny, dimensionless point of light — except that it flares up in the course of a day and fades out slowly over weeks or months.

To spot these intruding flashes, you must first be familiar with the normal appearance of the galaxies you're searching. Although this sounds like a prodigious chore, it isn't nearly as

The 199 Brightest Galaxies

NGC #	M #	Con	RA (1950)	Dec	RA (2000)	Dec	Mag	Type
55		Scl	00h12m	−39°28′	00h15m	−39°11′	7.8	sp
134		Scl	00 28	−33 31	00 30	−33 15	11.4	sp
157		Cet	00 32	−08 40	00 35	−08 24	11.1	sp
205		And	00 38	+41 25	00 40	+41 41	9.5	el
221	32	And	00 40	+40 36	00 43	+40 52	8.2	el
224	31	And	00 40	+41 00	00 43	+41 16	3.5	sp
247		Cet	00 45	−21 02	00 47	−20 46	10.7	sp
253		Scl	00 45	−25 34	00 48	−25 17	7.0	sp
S Mag Cloud		Tuc	00 51	−73 06	00 53	−72 50	2.8	ir
300		Scl	00 53	−37 57	00 55	−37 41	11.3	sp
488		Psc	01 19	+05 00	01 22	+05 15	11.2	sp
584		Cet	01 29	−07 07	01 31	−06 52	11.5	sp
598	33	Tri	01 31	+30 24	01 34	+30 39	5.8	sp
613		Scl	01 32	−29 40	01 34	−29 25	11.1	sp
628	74	Psc	01 34	+15 32	01 37	+15 47	9.3	sp
908		Cet	02 23	−25 01	02 25	−24 48	11.1	sp
936		Cet	02 25	−01 23	02 28	−01 09	10.3	sp
1023		Per	02 37	+38 51	02 40	+39 04	11.0	sp
1068	77	Cet	02 40	−00 14	02 43	−00 48	8.9	sp
1084		Eri	02 44	−07 47	02 46	−07 35	11.1	sp
1087		Cet	02 44	−00 43	02 46	−00 30	11.2	sp
1097		For	02 44	−30 29	02 46	−30 17	10.6	sp
1187		Eri	03 00	−23 04	03 03	−22 52	11.3	sp
1232		Eri	03 08	−20 46	03 10	−20 35	10.7	sp
1291		Eri	03 15	−41 19	03 17	−41 08	10.2	sp
1300		Eri	03 17	−19 36	03 20	−19 25	10.6	sp
1302		For	03 18	−26 14	03 20	−26 04	11.4	sp
1313		Ret	03 18	−66 41	03 18	−66 30	10.8	sp
1316	For A	For	03 21	−37 23	03 23	−37 12	10.1	sp
1332		Eri	03 24	−21 31	03 26	−21 20	11.2	sp
1365		For	03 32	−36 18	03 34	−36 08	10.5	sp
1380		For	03 35	−35 08	03 36	−34 59	11.5	sp
1395		Eri	03 36	−23 11	03 39	−23 01	11.3	el
1398		For	03 37	−26 30	03 39	−26 20	10.7	sp
1399		For	03 37	−35 37	03 39	−35 27	10.9	el
1404		For	03 37	−35 45	03 39	−35 36	11.5	el
1407		Eri	03 38	−18 44	03 40	−18 35	11.4	el
1433		Hor	03 40	−47 23	03 42	−47 13	11.4	sp
1549		Dor	04 15	−55 43	04 16	−55 36	11.0	el
1553		Dor	04 15	−55 54	04 16	−55 47	10.2	sp
1559		Ret	04 17	−62 54	04 18	−62 47	11.1	sp
1566		Dor	04 19	−55 03	04 20	−54 56	10.5	sp
1637		Eri	04 39	−02 57	04 41	−02 51	10.7	sp
1672		Dor	04 45	−59 20	04 46	−59 14	11.4	sp
1792		Col	05 04	−38 03	05 05	−37 59	10.7	sp
1808		Col	05 06	−37 35	05 08	−37 31	11.2	sp
L Mag Cloud		Dor	05 24	−69 48	05 24	−69 45	0.6	ir
2403		Cam	07 32	+65 43	07 37	+65 36	8.8	sp
2613		Pyx	08 31	−22 48	08 33	−22 58	10.9	sp
2683		Lyn	08h50m	+33°37′	08h53m	+33°25′	9.7	sp
2681		UMa	08 50	+51 30	08 54	+51 19	10.7	sp
2775		Cnc	09 08	+07 15	09 10	+07 02	10.7	sp
2841		UMa	09 19	+51 11	09 22	+50 59	9.4	sp
2903		Leo	09 29	+21 43	09 32	+21 30	9.7	sp
2997		Ant	09 43	−30 58	09 46	−31 12	10.5	sp
2976		UMa	09 43	+68 09	09 47	+67 55	11.4	sp
2985		UMa	09 46	+72 31	09 50	+72 17	11.3	sp
3031	81	UMa	09 52	+69 18	09 56	+69 04	7.0	sp
3034	82	UMa	09 52	+69 55	09 56	+69 41	8.4	sp
3079		UMa	09 59	+55 55	10 02	+55 41	10.6	sp
3077		UMa	09 59	+68 59	10 03	+68 44	10.9	ir
3109		Hya	10 01	−25 55	10 03	−26 09	11.2	sp
3115		Sex	10 03	−07 29	10 05	−07 43	9.3	sp
3147		Dra	10 13	+73 39	10 17	+73 24	11.3	sp
3166		Sex	10 11	+03 41	10 14	+03 26	11.5	sp
3169		Sex	10 12	+03 43	10 14	+03 28	11.4	sp
3184		UMa	10 15	+41 40	10 18	+41 25	9.8	sp
3198		UMa	10 17	+45 48	10 20	+45 33	11.0	sp
3310		UMa	10 36	+53 46	10 39	+53 30	10.1	sp
3344		LMi	10 41	+25 11	10 44	+24 55	11.0	sp
3351	95	Leo	10 41	+11 58	10 44	+11 42	10.4	sp
3359		UMa	10 43	+63 29	10 47	+63 13	11.0	sp
3368	96	Leo	10 44	+12 05	10 47	+11 49	10.4	sp
3377		Leo	10 45	+14 15	10 48	+13 59	11.4	el
3379	105	Leo	10 45	+12 51	10 48	+12 35	9.6	el
3384		Leo	10 46	+12 54	10 48	+12 38	10.2	sp
3489		Leo	10 58	+14 10	11 00	+13 54	11.3	sp
3486		LMi	10 58	+29 15	11 00	+28 59	11.2	sp
3521		Leo	11 03	+00 14	11 06	−00 02	9.2	sp
3556	108	UMa	11 09	+55 57	11 12	+55 40	10.1	sp
3585		Hya	11 11	−26 29	11 13	−26 45	11.3	el
3607		Leo	11 14	+18 20	11 17	+18 03	11.2	sp
3621		Hya	11 16	−32 32	11 18	−32 49	10.6	sp
3623	65	Leo	11 16	+13 22	11 19	+13 06	9.4	sp
3626		Leo	11 17	+18 38	11 20	+18 21	11.4	sp
3627	66	Leo	11 18	+13 16	11 20	+12 59	9.0	sp
3628		Leo	11 18	+13 52	11 20	+13 36	10.3	sp
3631		UMa	11 18	+53 27	11 21	+53 10	10.5	sp
3675		UMa	11 23	+43 52	11 26	+43 35	10.6	sp
3726		UMa	11 31	+47 18	11 33	+47 02	11.3	sp
3810		Leo	11 38	+11 45	11 41	+11 28	10.8	sp
3893		UMa	11 46	+48 59	11 49	+48 43	11.3	sp
3923		Hya	11 49	−28 32	11 51	−28 48	11.1	el
3938		Uma	11 50	+44 24	11 53	+44 07	11.2	sp
3941		UMa	11 50	+37 16	11 53	+36 59	11.3	sp
3949		UMa	11 51	+48 08	11 54	+47 52	11.5	sp
3953		UMa	11 51	+52 37	11 54	+52 20	10.1	sp
3992	109	UMa	11 55	+53 39	11 58	+53 23	9.9	sp

hard as it seems. For one thing, you can pick your galaxies and learn as you go — after all, there's nothing forcing you to memorize the appearance of all the galaxies overnight! Besides, in due time, you'll find that many galaxies will have slowly impressed their features onto your memory and you've "learned" them with little effort.

NGC-4565 by Lee Coombs

Of course, a detailed chart of a galaxy and its environs will aid you tremendously. Currently, the American Association of Variable Star Observers (see box on page 54) is preparing a series of charts — specifically for supernova searchers — which will show surrounding stars of known magnitude for comparison. In addition, the *Photographic Star Atlas* by Hans Vehrenberg and the *Hubble Atlas of Galaxies* are immensely helpful. Of the two, Vehrenberg's probably suits the small or medium-size telescope better, since photos in it will more closely resemble what you see. The *Hubble Atlas* is based on photographs taken through some of the world's largest instruments, and the discrepancy between eyepiece view and printed photo is sometimes great.

Thickets of foreground stars make some galaxies quite difficult to examine properly. One of the worst in this respect is M-31, which has a large surface area and a location well sprinkled with stars — many of which have set off false alarms. You shouldn't begin to search M-31 specifically for supernovae until you've spent a lot of time just looking at it and becoming thoroughly familiar with its appearance.

The galaxies NGC-2841, NGC-4102, M-81, and M-82 (all in Ursa Major); M-51 in Canes Venatici; and M-77 in

NGC #	M #	Con	RA (1950)	Dec	RA (2000)	Dec	Mag	Type
4030		Vir	11h58m	−00°49′	12h00m	−01°06′	11.2	sp
4038		Crv	11 59	−18 35	12 02	−18 52	11.0	sp
4051		UMa	12 01	+44 49	12 03	+44 32	10.2	sp
4088		UMa	12 03	+50 49	12 06	+50 32	10.6	sp
4096		UMa	12 03	+47 46	12 06	+47 29	11.5	sp
4125		Dra	12 06	+65 27	12 08	+65 11	11.1	el
4151		CVn	12 08	+39 41	12 11	+39 24	11.2	sp
4192	98	Com	12 11	+15 11	12 14	+14 54	10.7	sp
4214		CVn	12 13	+36 37	12 16	+36 20	9.9	sp
4216		Vir	12 13	+13 25	12 16	+13 09	9.9	sp
4236		Dra	12 14	+69 45	12 17	+69 28	9.8	sp
4244		CVn	12 15	+38 05	12 18	+37 49	10.2	sp
4242		CVn	12 15	+45 54	12 18	+45 37	11.5	sp
4251		Com	12 16	+28 27	12 18	+28 10	10.2	sp
4254	99	Com	12 16	+14 42	12 19	+14 25	10.1	sp
4258	106	CVn	12 16	+47 35	12 19	+47 18	8.4	sp
4274		Com	12 17	+29 53	12 20	+29 37	10.5	sp
4278		Com	12 18	+29 34	12 20	+29 17	11.4	el
4303	61	Vir	12 19	+04 45	12 22	+04 29	9.6	sp
4321	100	Com	12 20	+16 06	12 23	+15 49	10.6	sp
4365		Vir	12 22	+07 36	12 24	+07 19	11.0	el
4374	84	Vir	12 23	+13 10	12 25	+12 53	9.3	el
4382	85	Com	12 23	+18 28	12 25	+18 11	9.3	el
4395		CVn	12 23	+33 50	12 26	+33 33	11.4	sp
4406	86	Vir	12 24	+13 13	12 26	+12 57	9.7	sp
4414		Com	12 24	+31 30	12 26	+31 13	9.7	sp
4429		Vir	12 25	+11 23	12 27	+11 07	11.3	sp
4438		Vir	12 25	+13 17	12 28	+13 01	11.0	sp
4449		CVn	12 26	+44 22	12 28	+44 06	9.7	sp
4450		Com	12 26	+17 22	12 29	+17 05	10.1	sp
4472	49	Vir	12 27	+08 17	12 30	+08 00	8.6	el
4473		Vir	12 27	+13 42	12 30	+13 26	10.4	el
4490		CVn	12 28	+41 55	12 31	+41 38	9.8	sp
4486	87	Vir	12 28	+12 40	12 31	+12 24	9.2	el
4494		Com	12 29	+26 03	12 31	+25 47	10.7	el
4501	88	Com	12 29	+14 42	12 32	+14 25	10.2	sp
4517		Vir	12 30	+00 23	12 33	+00 07	11.4	sp
4526		Vir	12 32	+07 59	12 34	+07 42	10.7	sp
4527		Vir	12 32	+02 56	12 34	+02 39	11.3	sp
4535		Vir	12 32	+08 29	12 34	+08 12	10.7	sp
4536		Vir	12 32	+02 28	12 34	+02 11	11.0	sp
4546		Vir	12 33	−03 31	12 35	−03 48	11.4	sp
4548		Com	12 33	+14 46	12 35	+14 30	10.9	sp
4552	89	Vir	12 33	+12 50	12 36	+12 34	9.5	sp
4559		Com	12 33	+28 14	12 36	+27 58	10.5	sp
4565		Com	12 34	+26 16	12 36	+25 59	9.6	sp
4569	90	Vir	12 34	+13 26	12 37	+13 10	10.0	sp
4579	58	Vir	12 35	+05 39	12 38	+05 22	8.2	sp
4594	104	Vir	12 37	−11 21	12 40	−11 37	8.7	sp
4605		UMa	12 38	+61 53	12 40	+61 37	9.6	sp
4618		CVn	12 39	+41 27	12 42	+41 09	10.8	sp
4621	59	Vir	12h40m	+11°55′	12h42m	+11°39′	9.3	el
4631		CVn	12 40	+32 49	12 42	+32 32	9.3	sp
4636		Vir	12 40	+02 58	12 43	+02 41	10.8	el
4649	60	Vir	12 41	+11 50	12 44	+11 33	9.2	sp
4651		Com	12 41	+16 40	12 44	+16 24	10.8	sp
4654		Vir	12 41	+13 24	12 44	+13 08	11.2	sp
4656		CVn	12 42	+32 27	12 44	+32 10	11.0	ir
4666		Vir	12 43	−00 11	12 45	−00 28	11.4	sp
4697		Vir	12 46	−05 32	12 49	−05 48	10.5	el
4699		Vir	12 46	−08 24	12 49	−08 40	10.3	sp
4725		Com	12 48	+25 47	12 50	+25 30	9.5	sp
4736	94	CVn	12 49	+41 24	12 51	+41 07	7.9	sp
4753		Vir	12 50	−00 56	12 52	−01 12	10.6	sp
4762		Vir	12 50	+11 30	12 53	+11 14	11.5	sp
4826	64	Com	12 54	+21 57	12 57	+21 41	6.6	sp
4856		Vir	12 57	−14 46	12 59	−15 03	11.4	sp
4945		Cen	13 03	−49 12	13 05	−49 28	9.2	sp
4958		Vir	13 03	−07 45	13 06	−08 01	11.5	sp
5005		CVn	13 09	+37 19	13 12	+37 04	9.9	sp
5033		CVn	13 11	+36 52	13 13	+36 37	10.2	sp
5055	63	CVn	13 14	+42 18	13 16	+42 02	10.1	sp
5102		Cen	13 19	−36 22	13 22	−36 38	10.8	sp
5128	Cen A	Cen	13 23	−42 46	13 25	−43 01	7.5	sp
5194	51	CVn	13 28	+47 27	13 30	+47 12	8.4	sp
5195		CVn	13 28	+47 32	13 30	+47 16	11.0	sp
5236	83	Hya	13 34	−29 37	13 37	−29 52	10.1	sp
5248		Boo	13 35	+09 09	13 38	+08 53	11.3	sp
5253		Cen	13 37	−31 23	13 40	−31 39	10.8	ir
5322		UMa	13 48	+60 26	13 49	+60 12	11.3	el
5363		Vir	13 53	+05 30	13 56	+05 15	11.1	sp
5364		Vir	13 54	+05 16	13 56	+05 01	11.5	sp
5371		CVn	13 54	+40 42	13 56	+40 28	11.5	sp
5457	101	UMa	14 01	+54 36	14 03	+54 21	9.6	sp
5474		UMa	14 03	+53 54	14 05	+54 40	10.9	sp
5566		Vir	14 18	+04 10	14 20	+03 56	11.4	sp
5643		Lup	14 29	−43 57	14 33	−44 10	11.4	sp
5846		Vir	15 04	+01 48	15 06	+01 36	11.5	sp
5866	102	Dra	15 05	+55 57	15 06	+55 46	11.5	sp
5907		Dra	15 15	+56 30	15 16	+56 19	10.4	sp
6215		Ara	16 47	−58 54	16 51	−58 59	11.2	sp
6221		Ara	16 48	−59 08	16 53	−59 13	11.4	sp
6300		Ara	17 12	−62 46	17 17	−62 49	11.4	sp
6503		Dra	17 50	+79 10	17 49	+70 09	10.2	sp
6744		Pav	19 05	−63 56	19 10	−63 51	10.6	sp
6822		Sgr	19 42	−14 56	19 45	−14 48	11.0	ir
6946		Cep	20 34	+59 59	20 35	+60 09	11.1	sp
7217		Peg	22 06	+31 07	22 08	+31 22	10.2	sp
7331		Peg	22 35	+34 10	22 37	+34 25	9.6	sp
IC1459		Gru	22 54	−36 44	22 57	−36 28	11.3	el
7793		Scl	23 55	−32 52	23 58	−32 35	9.7	sp

Cetus lie almost in line with stars which at first glance could be mistaken for supernovae. Likewise, the field of NGC-891 in Andromeda is littered with several false candidates that are visible through an 8 or a 10-incher. At times like this, a good photograph, such as that on page 108 of the November 1980 ASTRONOMY will help prevent false alarms.

What *is* the likelihood of finding an extragalactic supernova? Realistically, your chances on any one night are pretty slim. But let's consider all the galaxies of magnitude 11.5 or brighter — most of which are visible through an 8-inch scope. Scattered over the whole sky are 199 examples, each listed in the table above.

If we assign a probability of one supernova per galaxy per century for

NGC-7331 by Martin Germano

just these elite 199, we would have something like an 85% chance of observing at least one supernova among them in a given year. If your scope is larger and allows you to set the magnitude limit lower — at 13.0, say — your chances increase substantially, since several hundred additional galaxies become available. (Carrying this argument to its logical end, we find one supernova explosion occurs every 10 seconds somewhere in the observable universe!)

Of course, the majority of the supernovae in the brightest several hundred galaxies lie beyond the reach of the small telescope, but plenty are still accessible. About three dozen since the 1885 outburst of S Andromedae have been brighter than magnitude 12.5. Of these, four (including S Andromedae itself) were discovered visually.

The most recent visual discovery was in the spring of 1979, when Gus

Johnson of Swanton, Maryland, noticed a 10th magnitude glow in M-100, a spiral galaxy in Coma Berenices. Although Johnson admits he was lucky to be looking in the right place at the right time, his case shows that the backyard astronomer can find a supernova.

To improve your odds, you can choose those galaxies most likely to harbor supernovae. Both relatively and absolutely, spiral galaxies are better candidates than either ellipticals or irregulars. One count of nearly 300 supernovae revealed that 247 of them occurred in spirals; only 30 were in ellipticals and 16 in irregulars.

NGC-1300 by David Healy

But these figures are a little misleading. Irregular galaxies are at a disadvantage to begin with, since they represent only about 5% of all galaxies. And stars in elliptical galaxies are generally not very massive, so their likelihood of becoming supernovae is small.

It's clear that your greatest chances for success are with the spirals — galaxies whose arms are replete with the gigantic, profligate, young stars that hurry through their brief lives and die spectacularly. But since elliptical and irregular galaxies occasionally spawn supernovae, you shouldn't eliminate them from your search program.

M-81 by Martin Germano

Even naked-eye observers have a chance. A supernova among the members of the Local Group of galaxies would probably be visible to the naked eye or in binoculars. The Local Group consists of our Galaxy, the two Magellanic Clouds, M-31 and its four small elliptical satellite-galaxies, M-33, about twenty scattered dwarf members, and probably other members hidden by the obscuration of our Galaxy itself.

The Magellanic Clouds are fairly good candidates for a supernovae watch because they each contain a respectable number of massive stars. In fact, the Large Cloud apparently has at least three supernova remnants. At a distance of about 200,000 light-years, a supernova in either Cloud would rival the brighter stars in our sky — though it would probably be dimmer than one in our own Galaxy proper.

A supernova in one of the dwarf members of the Local Group would be spectacular, surpassing the luminosity of its galaxy several thousand times — but the extremely low stellar populations in such galaxies all but eliminate the possibility. By comparison, supernovae in our Galaxy or M-31, though rare in terms of human experience, are cosmically abundant.

NGC-4631 by Martin Germano

Certain other galaxies, for example NGC-6946 in Cepheus and IC 342 in Camelopardalis, are possibly remote members of the Local Group. Whether it is or not, NGC-6946 is worth a regular patrol because six supernovae have been recorded there in the last 65 years: in 1917, 1939, 1948, 1968, 1969, and most recently, in October 1980. The brightest of them, the explosion of 1939, attained magnitude 11.8.

The options open to a supernova searcher are many. A glance through small binoculars at a bright neighboring galaxy or a series of careful scans through a large telescope into deep space could both lead to a find. The choice of methods lies with you, though systematic searches are more likely to be successful.

how to join the supernova patrol

Telescope owners who want to patrol for supernovae should write to the American Association of Variable Star Observers (AAVSO), 187 Concord Ave., Cambridge, MA 02138. Enclose a stamped self-addressed business envelope.

A supernova patrol can also increase the fun you get out of observing. By putting some additional structure into what you do, you can transform a night under the stars from a hit-or-miss affair into a more meaningful venture. And apart from the scientific value of finding a supernova, you can also feel awed by the sight, or even the thought, of an exploding star — brute force that could instantly vaporize a thousand Earths.

We marvel from our safe distance — and remind ourselves that our star, the Sun, will never do the same. Fortunately for us, this holds true for the Sun's nearby stellar neighbors, too. If one of the nearest stars were to explode as a supernova, excessive amounts of radiation would pour through the solar system and destroy what's left of our planet's delicate ecology.

Breathing a small sigh of relief and knowing that — for the present at least — you are safe from death by starfire, you may sit back comfortably at your telescope and ready yourself to watch for the next beacon from a distant galaxy.

M-101 by Howard McCallon

Michael Witkoski has been observing galaxies and other deep-sky objects for many years. His last article for ASTRONOMY, "Observing Planetary Nebulae," appeared in June 1981.

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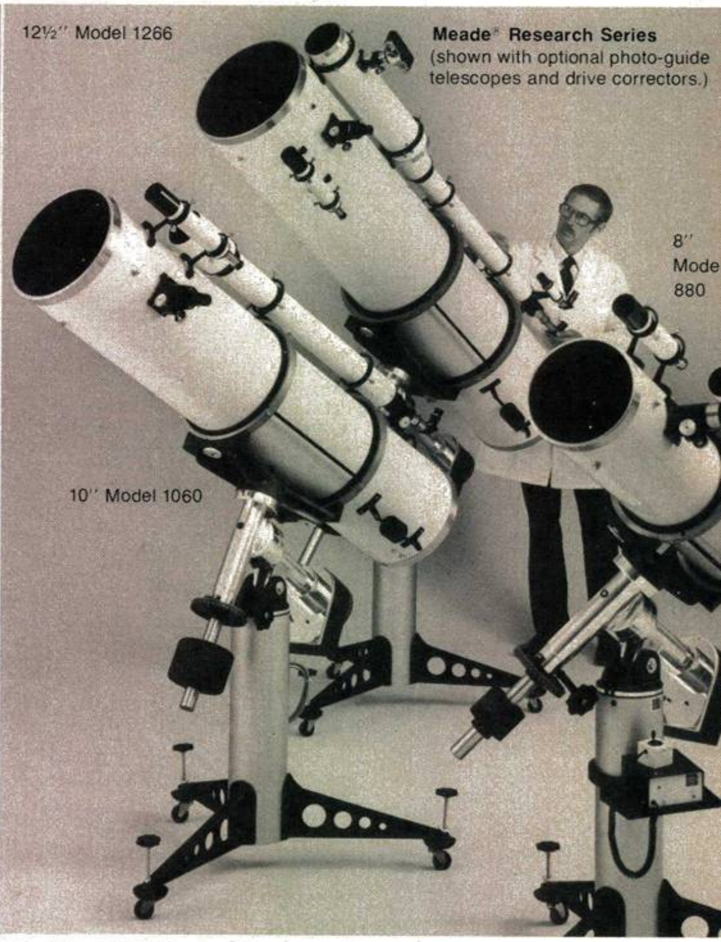
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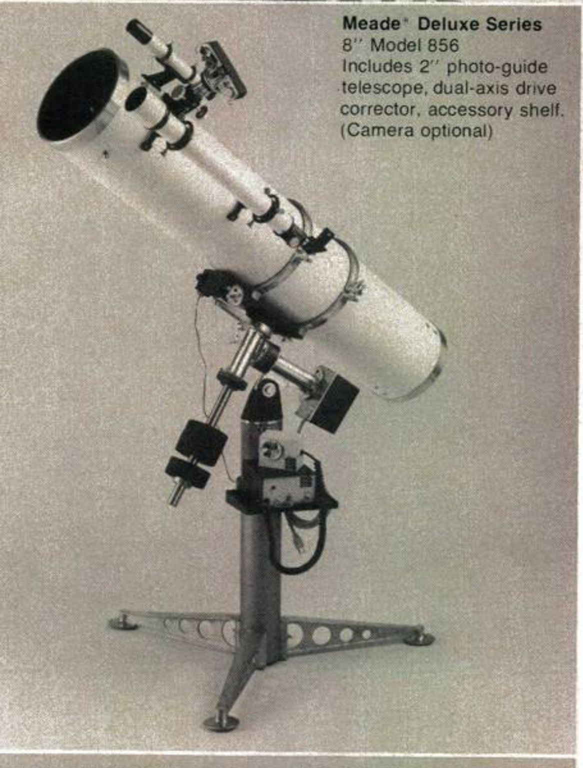
Meade® Deluxe Series
8″ Model 856
Includes 2″ photo-guide telescope, dual-axis drive corrector, accessory shelf.
(Camera optional)

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Meade
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Meade Standard Series 6″ and 8″ Reflecting Telescopes—Compare feature-for-feature with any compe
ing 6″ and 8″ telescopes—these are the finest values obtainable, bar none. Includes exact same 1/10-wav
optics of Deluxe and Research Series. Mounts machined to .001″ tolerances for a lifetime of precisio
tracking, visually and photographically; Polar and Dec. Shafts 1″ dia. solid steel. Motor drive (115v./60Hz
included, with automatic clutch, 6 ft. cord, and safety **3-prong** grounded plug. Complete with setting circles,
coated Kellner eyepieces (49X, 135X) threaded for filters, 6 x 30 achromatic viewfinder, rack-and-pinio
focuser, rotating ring system. Strong Fiberlite tube with attractive white coating. Excellent astrophotographi
capabilities with your 35mm camera, prime-focus or eyepiece-projection. Optional eyepieces and 2
Telenegative Barlow for powers to 350X (Model 592) and 610X (Model 791). **Immediate delivery o
both models.**

Meade Deluxe Series 6″ and 8″ Reflecting Telescopes—The most popular reflecting telescopes in th
World for the serious amateur. All the capabilities and features of the Standard Series, and more. Large
ball-bearing equatorial mount permits addition of optional Dual-Axis Drive Corrector or Manual Dec. Contro
for long-exposure photography, as well as the addition of heavier auxiliary instrumentation. Complete wit
Motor Drive (115v./60Hz) and automatic clutch, setting circles, 2 **multi-coated** Modified Achromati
eyepieces (49X, 135X) threaded for filters, 6 x 30 achromatic viewfinder, rack-and-pinion focuser, rotatin
ring system. Fiberlite tube with ultrahard white epoxy coating and metal trim rings. Available with gian
focuser and/or viewfinder substitutions, if desired.

Meade Research Series 8″, 10″, 12½″ Reflecting Telescopes—For the advanced observer/astrophotog
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ter ball-bearings, 1½″ solid steel shafts, 5″-dia. worm gear drive system, 6″ engraved setting circles, an
machined Nylon-bearing tube rotation system. Standard accessories: giant focuser for 1¼″ and 2″ O.D
8 x 50 viewfinder, 2 multi-coated Orthoscopic eyepieces.

PRICE LIST

COMPLETE STANDARD SERIES TELESCOPES	
Model 592: 6″ f/8 with Motor Drive	$ 349.95
Model 791: 8″ f/6 with Motor Drive	479.95
COMPLETE DELUXE SERIES TELESCOPES	
Model 628: 6″ f/8 with Motor Drive	$ 419.50
Model 645: 6″ f/5 with Motor Drive	427.50
Model 826: 8″ f/6 with Motor Drive	529.50
Model 856: 8″ f/6 with Motor Drive, 2″ Guide Telescope, Dual-Axis Drive Corrector, Accessory Shelf	835.00

COMPLETE RESEARCH SERIES TELESCOPES	
Model 880: 8″ f/6 with Motor Drive	$1250.00
Model 1060: 10″ f/6 with Motor Drive	1595.00
Model 1266: 12½″ f/6 with Motor Drive	1975.00
COMPLETE EQUATORIAL MOUNTS	
Model 652: 6″ with Motor Drive	$ 199.50
Model 852: 8″ with Motor Drive	219.50
Model 1071: 10″ with Motor Drive	825.00
Model 1277: 12½″ with Motor Drive	865.00

All prices **include** packing; F.O.B. Costa Mesa, Calif.

Complete 52-Page General Catalog #82-W —$3.00

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PHOTO-GUIDE TELESCOPES— Each with coated, air-spaced objective, rack-and-pinion focuser, diagonal prism, 9mm crosshair eyepiece.

1— **Model 300PG:** D=80mm (3.1"); F=1200mm (f/15) **$185.00 ppd.**
2— **Model 280PG:** D=60mm (2.4"); F=700mm (f/11.7) **72.50 ppd.**
3— **Model 210PG:** D=50mm (2.0"); F=600mm (f/12) .. **57.50 ppd.**
Mounting Rings: for #210PG ..... per. pr. **7.75 ppd.**
for #280PG, #300PG ..... per. pr. **12.50 ppd.**

RACK-AND-PINION FOCUSERS— All 3 models include helical-cut rack and variable-tension adjustment for ultra-smooth focusing without backlash. Universal bases fit all tube sizes. Standard 1¼" eyepiece holders.

4— **Model 67** — Strong, lightweight design for 4" to 10" telescopes. 2-3/16" travel. An excellent value. **$23.50 ppd.**
5— **Model 640** — A heavy-duty deluxe focuser for 6" to 16" telescopes. Full 3" travel for both visual and photographic applications. **$36.95 ppd.**
6— **Model 680** — Accepts both 1¼" and 2" eyepieces. Full 3" travel for photo or visual observing with 6" to 16" telescopes. **$44.95 ppd.**

ACCESSORY CASES— For secure storage of eyepieces, Barlows, filters.

7— **Model 54:** Thick-wall polyethylene with latch and handle. Holds 7 eyepieces & Barlow, filters. Dims. 12" × 8" × 3¾" **$12.50 ppd.**
8— **Model 50:** Luggage-quality metal case with 2 latches, handle; foam custom fits to your accessories.
Dims. 20" × 12" × 6½" .... **$39.50 ppd.**

NEBULAR FILTERS—Revolutionary 3-channel filters block natural airglow & sodium and mercury emissions from city lights. Dramatically improve telescope performance visually and photographically.

9— **Model 907:** 18mm aperture, for .965" O.D. eyepieces **$42.50 ppd.**
10— **Model 908:** 23mm aperture, for 1¼" O.D. eyepieces **$49.95 ppd.**
11— **Model 911:** 36mm aperture, threads directly onto rear-cell of Meade and Celestron Schmidt-Cassegrains. .... **$69.50 ppd.**

12— **PHOTO-VISUAL COLOR FILTERS**— Top quality optical glass, dyed-in-the-mass, with excellent spectral homogeneity. Thread directly into 1¼" O.D. barrels. Filters may be piggybacked. **#8 Light Yellow—#11 Yellow-Green—#12 Yellow—#21 Orange—#23A Light Red—#25A Red—#47 Violet—#58 Green—#80A Blue—Polarizer (30% transmission).** Each filter: **$7.50 ppd.** Set of any 6: **$41.50 ppd.**— Full set of 10: **$65.00 ppd.**

13— **VARIPAK DRIVE CORRECTOR— Model 43:** Supercompact 2" × 3" × 4" design. Fast-slow pushbuttons. Variable speed control. Operates from 12 volts D.C., plugs into standard auto cigarette lighter. The 12-watt output is sufficient for most telescopes to 14" aperture .... **$59.50 ppd.**

14— **VARIGUIDE DRIVE CORRECTOR— Model 41:** The finest R.A. drive corrector available. Includes aircraft-type joystick controller for continuously variable correction rates. Variable speed control. Use with any telescope drive rated up to 12 watts. Operates from 12 v. D.C. or 115 v. A.C. **$99.50 ppd.**

15— **6 × 30mm VIEWFINDER— Model 631:** Same unit supplied as standard equipment on Meade 6" and 8" reflecting telescopes. Actual field: 4°. Includes coated, achromatic objective lens and crosshair eyepiece. Precise push-pull focusing. Thousands now in use. Bracket, with collimation screws and lock-nuts, included. Bracket fits all tubes 6" to 12½". **$24.50 ppd.**

16— **6 × 30mm RIGHT-ANGLE VIEWFINDER— Model 633:** As in (15), but with prism for convenient right-angle observations. Prism may be rotated 360° for maximum viewing comfort. 2-ring bracket included. **$29.50 ppd.**

17— **SERIES 1 KELLNER EYEPIECES (1¼" O.D.)**—High-quality, fully-coated optics housed in chromed barrels threaded for filters. Sold elsewhere for $18.00 to $22.00. **KE 9, 25, 40mm** .... each **14.75 ppd.**

18— **SERIES 1 ORTHOSCOPIC EYEPIECES (1¼" O.D.)**— Well-corrected 4-element designs, fully coated, threaded for filters. Sold elsewhere for $26.00 to $30.00. **OR 4, 6, 9, 12.5, 25mm** .... each **$23.75 ppd.**

19— **SERIES 2 MODIFIED ACHROMATIC EYEPIECES (1¼"O.D.; MULTI-COATED)**—Custom 3-element designs, precisely corrected for chromatic and spherical aberrations. Finest obtainable under $20.
FOCAL LENGTHS: MA 6,9,12,25mm, 40mm Wide-Field, ea. $18.95 ppd.

20— **MODIFIED ACHROMATIC 40mm EXTRA-WIDE-FIELD EYEPIECE (1¼" O.D.; MULTI-COATED)**—Yields widest field obtainable in 1¼" O.D. Enlarged field lens and special field-flattening optics with long eye relief. **$27.50 ppd.**

21— **SERIES 2 ORTHOSCOPIC EYEPIECES (1¼" or .965" O.D.; MULTI-COATED; PARFOCAL)**— The excellent 4-element high resolution optics of these oculars are all the majority of serious amateurs ever require. Razor sharp 45° fields. Both 1¼" and .965" O.D. sets parfocalized.
FOCAL LENGTHS: OR 4, 6, 9, 12.5, 18, and 25mm .. each $27.50 ppd.

22— **RESEARCH-GRADE ORTHOSCOPIC EYEPIECES (1¼" O.D.; MULTI-COATED; PARFOCAL)**—The largest selling premium-quality eyepieces in the world, universally acclaimed to be the finest eyepieces obtainable. 4-element systems, unsurpassed in color correction, resolution, and flatness of field. 45° field. **OR 4, 7, 10.5, 16.8, 28mm** .... **each $39.95 ppd.**

23— **RESEARCH-GRADE ERFLE EYEPIECES (1¼" O.D.; MULTI-COATED; PARFOCAL)**— For breathtaking wide-angle observations. 65° fields, parfocalized with our Research-Grade Orthoscopics.
FOCAL LENGTHS: ER 7, 12.4, 15.5, 20mm .... **each $44.95 ppd.**

VIEWFINDERS— With helical focusers for ultraprecise control of image sharpness. Coated, achromatic objectives of new Meade design yield fully corrected images throughout the field. Actual field on 50mm models: 4¼°; on 60mm models: 3½°. Crosshair eyepiece, dewcap, dustcap included.

24— **8×50mm— $46.50 ppd.** Brackets: **$7.75/pr. ppd.**
25— **8×50mm RIGHT-ANGLE— $53.50 ppd.** Brackets: **$7.75/pr. ppd.**
26— **GIANT 9×60mm— $65.00 ppd.** Brackets: **$12.50/pr. ppd.**
27— **GIANT 9×60mm RIGHT ANGLE— $71.50 ppd;** Brackets: **$12.50/pr.**

28— **RESEARCH-GRADE ERFLE 32mm EYEPIECE (2" O.D.; MULTI-COATED)**—Wide-angle, fully-corrected 65° field. The finest eyepiece obtainable in 2" barrel. **$89.50 ppd.** Adapter Barrel for 1¼" O.D. **$10.75 ppd.**

29— **DELUXE CAMERA ADAPTERS**— Adapt your camera to telescope focuser instantly. Individually machined from solid bar aluminum and brass. All units permit both eyepiece-projection and first (prime) focus photography. Specify your camera brand and either 1¼" or .965" focuser. All 1¼" units are threaded for filters. **Nikon, Canon, Minolta, Pentax K, Konica, Olympus OM, or Universal Thread-Mount** .... **$29.50 ppd.**

30— **2X and 3X TELENEGATIVE AMPLIFIERS (1¼" O.D.; MULTI-COATED)**— Warranted without qualification to be the world's finest Barlow lenses. Full 26mm clear apertures, Multi-Coated, with virtually flawless optical corrections at all photo-visual wavelengths on any telescope. **2X Model 122: .. $29.50 ppd.; 3X Model 123: . . . $32.50 ppd.; 2X Model 131:** Per Model 122, but for .965" focusers; 18mm clear aperture, Multi-Coated. **$22.50 ppd.**

31— **2X-3X VARIABLE TELENEGATIVE AMPLIFIER (1¼" O.D.; MULTI-COATED)— Model 127:** Made to same research standards as Model 122 above, but mounted in a machined sliding cell, for variable power settings between 2X and 3X. Engraved scale indicates power. Multi-Coated . . . **$39.95 ppd.**

32— **PARABOLIC MIRRORS**— The very finest. 1/10-wave, diffraction-limited primary mirrors. Aluminized and quartz overcoated. Immediate shipment. **6"f/8 . . . $65.00 ppd.; 6" f/5 . . . $75.00 ppd.; 8" f/6 . . . $95.00 ppd. 10" f/6 . . . $175.00 ppd.; 12½" f/6 . . . $295.00 ppd.**

33— **SECONDARY MIRRORS**— Elliptical 1/10-wave flats. Aluminized and overcoated. Immediate shipment. **1.30" M.A. . . . $12.00 ppd.; 1.52" M.A. . . . $16.00 ppd.; 1.83" M.A. . . . $19.50 ppd.; 2.14" M.A. . . . $23.00 ppd.; 2.60" M.A. . . . $27.50 ppd.; 3.10" M.A. . . . $47.50 ppd.**

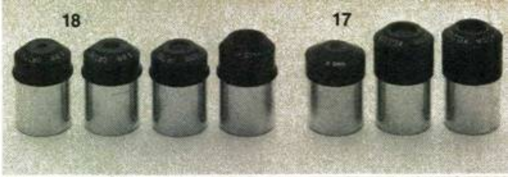
34— **ILLUMINATED RETICLE GUIDING EYEPIECE (1¼" O.D.)**—New phosphorescent etched double-line reticle permits line illumination from dim to extremely bright. Remote brightness control and 6 ft. cable. Modified Achromatic 12mm optical system. Precisely focusable reticle. Complete . . . **$49.95 ppd.** Interchangeable barrel for .965" O.D.. . . **$7.50 ppd.**

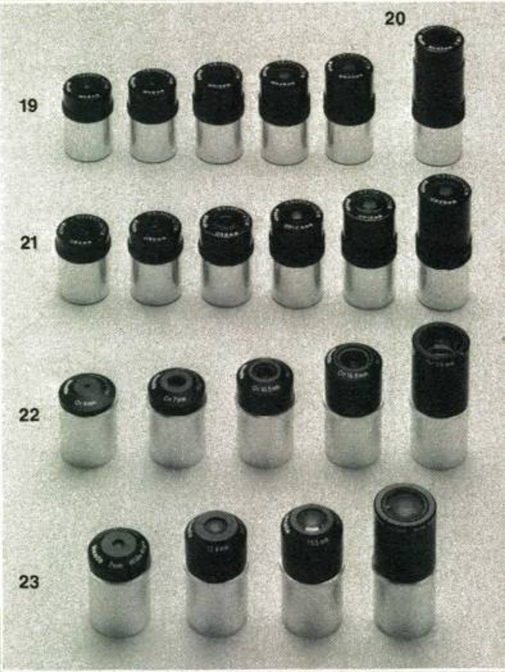
35— **MICROMETER RETICLE**—Full-field scale for accurate measurements of double star separations, planetary angular diameters, etc. Interchanges with standard 4-line reticle of Item (34), above . . . **$19.50 ppd.**

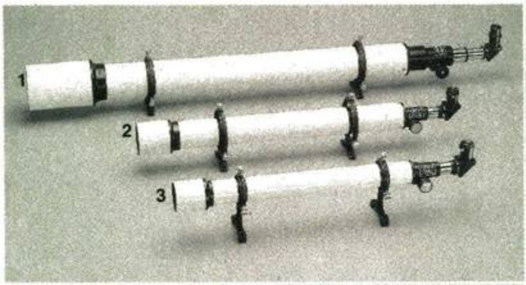
36— **ERECTING PRISMS**—Fully coated Porro prisms. Invert the astronomical image for terrestrial observations with astronomical telescopes. **1¼" O.D. . . . $29.75 ppd.; .965" O.D. . . . $25.75 ppd.**

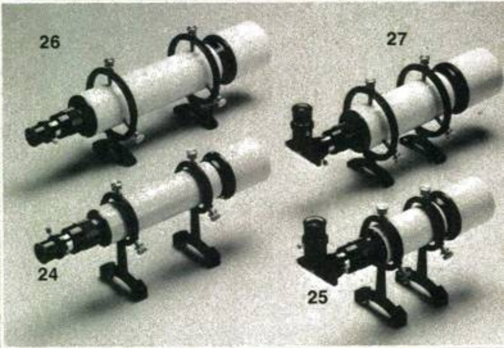
DIAGONAL PRISMS— Optical-quality right-angle prisms, fully coated.

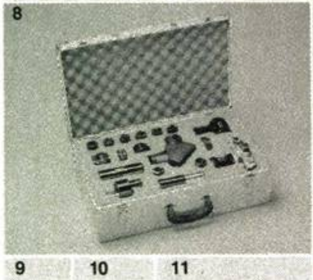
37— **Model 915:** Fits .965" focusers, accepts .965" eyepieces **$16.95 ppd.**
38— **Model 917:** Hybrid diagonal— fits .965" focusers, accepts 1¼" O.D. eyepieces .... **$26.95 ppd.**
39— **Model 918:** 18mm clear aperture. Fits 1¼" focusers, accepts 1¼" eyepieces .... **$22.95 ppd.**
40— **Model 918A:** 30mm clear aperture. Fits 1¼" focusers, accepts 1¼" eyepieces. Enlarged aperture increases field at low power **$26.95 ppd.**

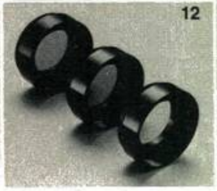


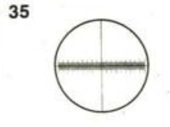


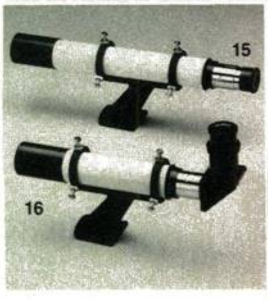












Meade Model 2080 8″ Schmidt-Cassegrain

Meade Model 2080
Shown with optional equatorial wedge and field tripod.

Research-Quality Accessories for Meade and Celestron Schmidt-Cassegrains

All of these Meade accessories are of the finest optical and mechanical quality available, and all (except item H) may be used interchangeably on Meade and Celestron Schmidt-Cassegrains.

PRICE LIST

A—	**Off-Axis Guider Body**	**$42.50 ppd.**
B—	**T-Adapter**	**17.50 ppd.**
C—	**Tele-Extender**	**17.50 ppd.**
	T-Rings (specify camera brand)	each **10.00 ppd.**
D—	**Telecompressor Lens** (f/5), Multi-Coated	**37.50 ppd.**
E—	**Extender Tube** (to use Telecompressor with Off-Axis Guider)	**11.50 ppd.**
F—	**Wide-Field Adapter Systems** (Visual Telecompressors) Includes Telecompressor Lens, Special T-Adapter, and Diagonal Prism.	
	For .965″ eyepieces	**71.50 ppd.**
	For 1¼″ eyepieces	**77.50 ppd.**
G—	**2″ Diagonal Mirror.** Includes adapters for 1¼″ and 2″ O.D. eyepieces	**149.95 ppd.**
H—	**Dual-Axis Drive Corrector, Model 46**—Attaches in 2 minutes to Meade Models 2080 or 2080C. No drilling required. Includes R.A. drive corrector, Dec. motor and clutch system, joystick controller. Operates from 115v. /60Hz or 12v.D.C.	**219.50 ppd.**
I—	**Solar Filters**—Optical glass, Inconel-coated, for professional-level solar observation. For Meade 2080 or Celestron 8.	
	#955: 8″ Full-Aperture Solar Filter	**165.00 ppd.**
	#956: 3″ Off-Axis Solar Filter	**90.00 ppd.**
J—	**Series 6 Drop-In Filters** (not shown). Optical glass. Includes Pink, Yellow, Yellow-Green, Red, Blue, Neutral (0.6). Set of 6 filters	**35.00 ppd.**

For Nebular Filters, Thread-In Filters, Drive Correctors, Barlow Lenses, Illuminated Reticle Eyepieces, and Erecting Prisms, see the accessories listing on the facing page. These accessories are fully compatible with Meade and Celestron Schmidt-Cassegrains.

Now Crown Optics breaks the price barrier on the World's finest 8″ Schmidt-Cassegrains. Order the renowned Meade Model 2080 from us and save hundreds of dollars off the list price:

Meade Model 2080 8″ Schmidt-Cassegrain— This is the telescope that is revolutionizing modern amateur astronomy and astrophotography. Supplied complete as shown with: ball-bearing fork mount, motor drive, 6 ft. power cord, dual slow motion controls, setting circles, 6 x 30mm viewfinder, diagonal prism, luggage-quality carrying case, and 2 multi-coated Modified Achromatic eyepieces (9mm and 25mm), dust covers, instruction manual . . . **$719.95**

Meade Model 2080C 8″ Schmidt-Cassegrain— Identical in all specifications to the Model 2080 above, but with 2 fully-coated Kellner eyepieces (9mm and 25mm) in place of the Modified Achromatic eyepieces, and with rugged foam-lined gift carton packing substituted for the carrying case . . . **$679.95**

Crown Optics purchases these 8″ Schmidt-Cassegrains in large quantities (up to 500 at a time) from Meade Instruments, so that the Models 2080 and 2080C are normally available for **immediate** shipment direct to your door anywhere in the U.S.A. and Canada.

Telescopes are a full-time business with us. Both before and after your purchase our highly qualified staff of 23 technical, order-desk, and shipping personnel are available Mon. - Fri. 8:30 - 5:00 to answer your questions, whether concerning an anticipated order or the use and application of a telescope or accessory you have already received.

PRICE LIST

MEADE MODEL 2080: 8″ SCHMIDT-CASSEGRAIN TELESCOPE	Base price, complete	**$719.95**
MEADE MODEL 2080C: 8″ SCHMIDT-CASSEGRAIN TELESCOPE	Base price, complete	**679.95**
Meade Equatorial Wedge for 2080/2080C		**50.00**
Meade Variable-Height Field Tripod for 2080/2080C		**125.00**
Meade High Transmission Coating		**70.00**

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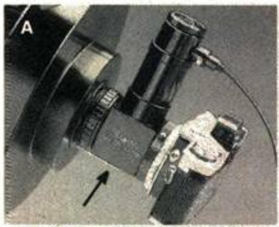

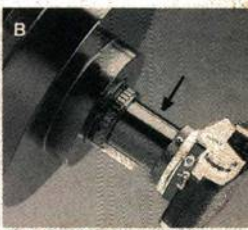

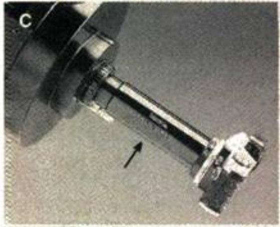

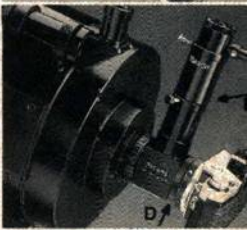

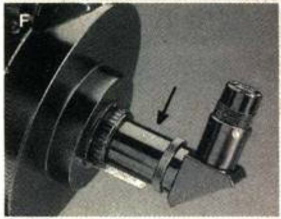

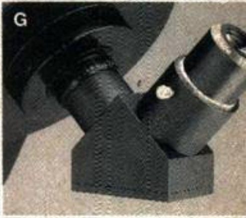

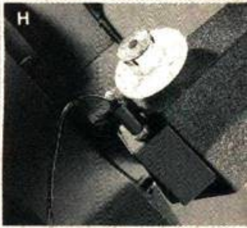

Toll-Free Phone-Order Desk for VISA and Master Card Holders or for C.O.D. Orders, dial

800-854-7485 (orders only)

from anywhere in the continental U.S.A., except California. Order Desk Hours: 8:30 - 5:00 Pacific Time Monday through Friday

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ORDERING INFORMATION

1. **Mail and Phone Orders only!** No dealer sales.
2. **Payment.** Personal or bank check, money order, VISA, or Master Card. (Immediate shipment on complete telescopes requires payment by cashier's check, M.O., or credit card.)
3. **All orders** are financially guaranteed by Meade Instruments Corporation.
4. **All products** are brand-new (no "seconds"!) and are normally available for immediate shipment.
5. **Within the U.S.A.:** Shipment by United Parcel Service direct to your door, fully insured, safe arrival guaranteed. **Canadian Orders:** See our Order Form for further details.
6. **All products** carry the Meade Instruments Full-Year Limited Warranty, and are backed by the Crown Optics reputation for trust and fair-dealing with our customers.
7. **California residents:** Add 6% Sales Tax.
8. **Outside North America:** Contact your Meade Instruments international distributor, or write directly to Meade Instruments Corporation for ordering information.

Coming next month! Meade 10″ Schmidt-Cassegrains at the World's Lowest Price!

CROWN**OPTICS,** INC.
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Authorized Meade Dealer

Burglar Alarm

A computerized burglar alarm requires no installation and protects your home or business. It is the first real alternative to a thousand dollar or more professional system.

The Midex 55 alarm system measures only 4" x 10½" by 7" yet protects you like much larger and expensive security systems.

The concept is simple. Provide all electronic functions of a professional wired together system. Put sensing and control into one easy-to-use device. Use large scale integration of solid state components to achieve lower cost and greater reliability. Here are some of the exciting features:

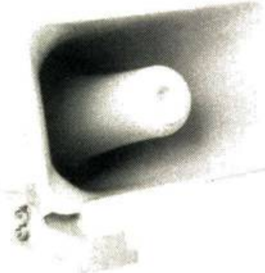
Invisible Protection. The Midex 55 protects your home using exactly the same technology that police radars use to catch speeding cars and trucks. When you are not at home, the Midex 55 generates a low energy radar field that detects anyone who moves in a designated area of your house. The protection pattern is an adjustable tear drop shape with maximum dimensions of 50 x 20 feet.

Loud Alarm. When the system detects an intruder, it turns on a loud police type electronic siren. The sound is loud enough to cause pain. It is loud enough to drive a burglar away before he can steal or damage your valuables. It is loud enough to alert your neighbors and, more important, loud enough to warn you not to enter your home before the police arrive.

Computerized Controls. To turn the system on, you punch in your personalized 4 digit access code. You now have 30 seconds to leave your home or office. When you return, you enter and disarm the system with your access code. You have 30 seconds to do that also.

When the Midex senses an intruder, it remains silent for 30 seconds. It then sounds the alarm until 8 minutes after the burglar leaves. The alarm then shuts off and resets, once again ready to do its job. This shut-off feature, not found on many expensive systems, means that your alarm won't go wailing all night long while you're away.

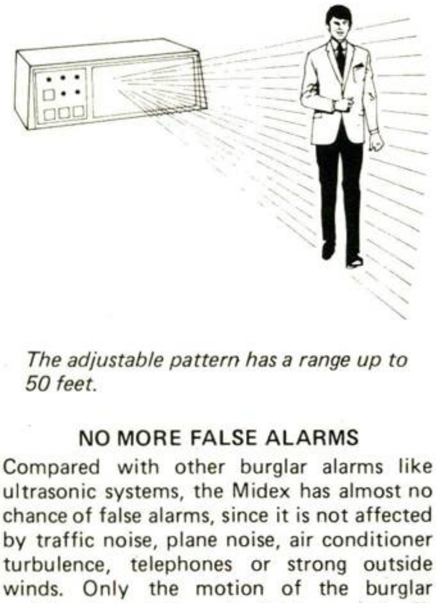
Standby Power. Should AC power fail or a smart burglar cut your AC power lines, the Midex 55 automatically switches to FAIL-SAFE operation using a built-in rechargeable battery pack. You are protected no matter what.



EXPANDABLE SYSTEM

You can set up the Midex in your own home in minutes. It looks like a stereo component. Just plug it into a wall socket, aim and adjust its protection pattern and connect two wires to the powerful alarm blast horn SP-30. If you wish, you can connect two alarm blast horns. If you connect 2 blast horns, we recommend one outside and one inside. A test light allows you to easily determine the area of coverage of the protection pattern. A thumb wheel lets you adjust it to your needs.

As an extra security measure, you can connect one or more panic buttons to the Midex. The panic buttons activate the alarm even with the radar protection pattern turned off. But even if you don't use the expansion features, the Midex is complete, ready to protect you, just as it arrives in its well-protected carton.



The adjustable pattern has a range up to 50 feet.

NO MORE FALSE ALARMS

Compared with other burglar alarms like ultrasonic systems, the Midex has almost no chance of false alarms, since it is not affected by traffic noise, plane noise, air conditioner turbulence, telephones or strong outside winds. Only the motion of the burglar walking through the radar field can set it off.

COMPARED AGAINST OTHERS

The Midex compares with much more expensive professionally installed systems. Yet it costs no more than do-it-yourself alarms purchased at retail. In a recent article, a leading consumer magazine rated the Midex tops in space protection, alarm siren power and immunity from false alarms. Don't be confused. There is no system under $1000 that provides you with the same protection.

The powerful blast horn has a 120dB output and makes a sound so loud it causes pain.

U.L. APPROVED SYSTEM

If you have owned a burglar alarm for more than a year, there's a good chance that it has required service. The Midex, however, is solid state and built with the same heavy duty components in industrial systems. The Midex is made by Solfan Systems, Inc., the leader in the production of radar detectors for commercial and industrial security systems. Solfan has made more than half a million industrial radar sensors and over 100,000 Midex 55. Will the Midex ever need service? No product is perfect. If you ever have a problem, call us on our toll free "help line" at (800) 227-8167. The product has a limited 1 year parts and labor warranty.

STANDING BEHIND A PRODUCT

The Midex protects more than 100,000 American homes. But the true test of how it performs is in your home or office. That is why we provide a one month trial period. We give you the opportunity to see how fail safe and easy to operate the Midex system is and how thoroughly it protects you and your loved ones. Decide after one month whether or not you want to keep it. If you decide to keep it, you'll own the best. If not, return your unit for a full and prompt refund. There is no risk.

Purchase the Midex 55 now for $199.95 and the SP-30 blast horn for $39.95. We recommend the purchase of two blast horns. To order, simply send your check to the address shown below. California residents add 6% sales tax. Credit card buyers may call our toll free number below. There are no postage or handling charges. The unit will be sent to you complete with all instructions.

Midex gives you everything you could possibly expect from a burglar alarm: 1) a professional grade system at a very reasonable price, 2) toll free telephone assistance, 3) the chance to buy a unit in complete confidence, knowing that you may return it if it's not exactly what you want. You can't lose.

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bloopers

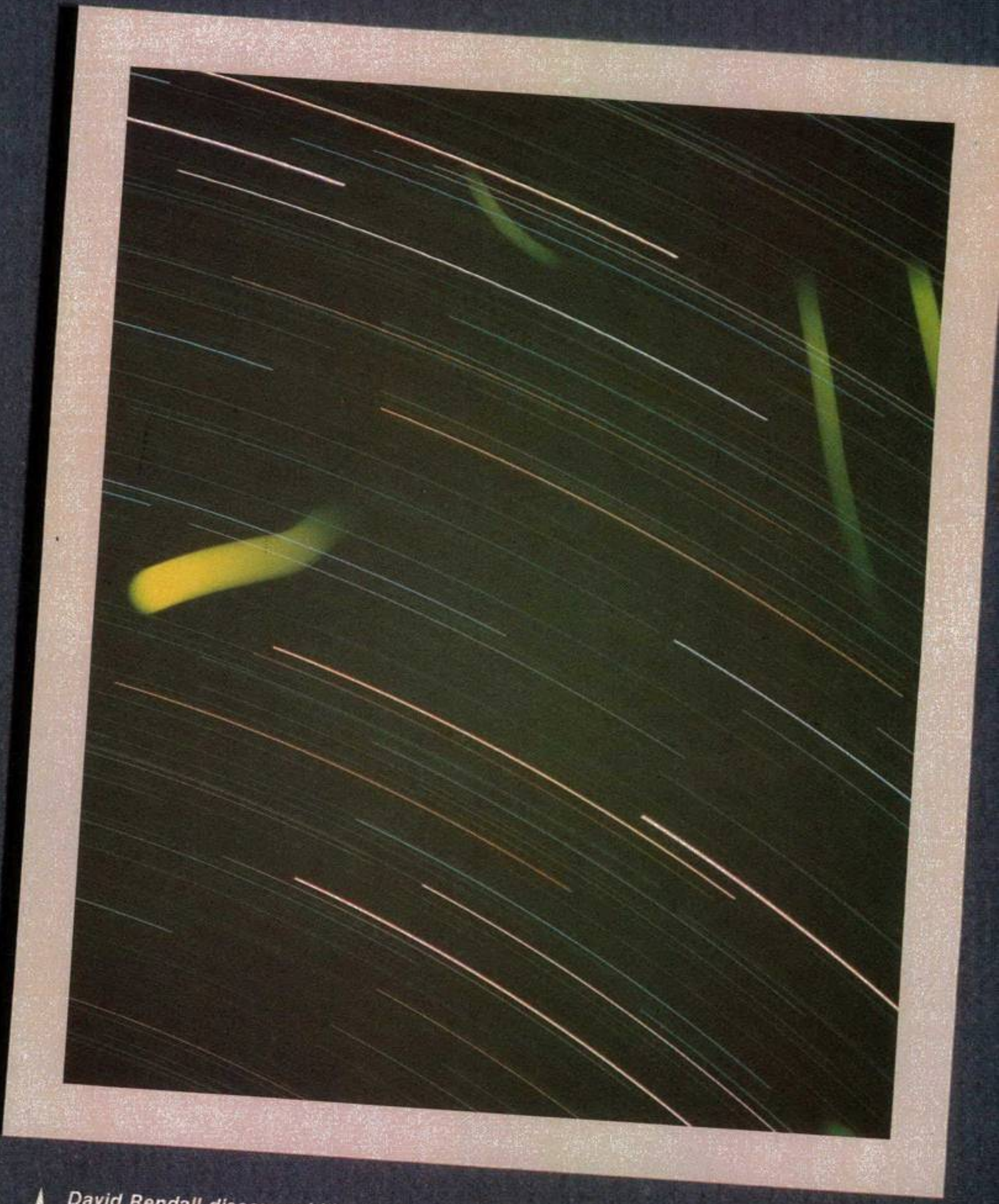
photography in astronomy

Astrophotography is tricky — no doubt about it. So many things can go wrong, and each one has the potential to blur, streak or otherwise ruin your finished photos. So you have to keep on your toes and avoid pitfalls every step of the way if you want your pictures to resemble something more than abstract art.

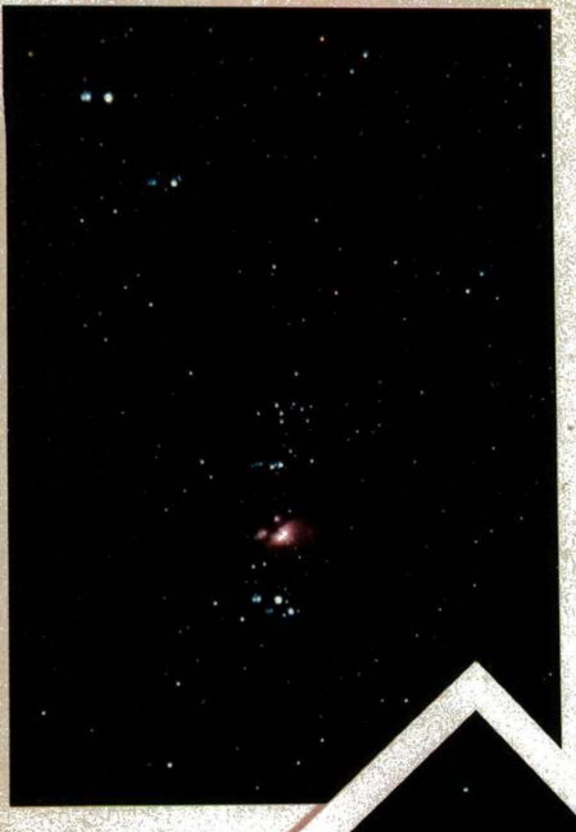
Start by watching out for common sense problems — like not taking off the lens cap for your one-hour exposure of M-82, or simply forgetting to align your scope on Polaris. Just plain clumsiness hurts too — like kicking a tripod leg while you're wandering around in the dark, or bumping the tube in the middle of a long exposure as you strain to peek through your off-axis guider.

But how can you deal with the problems you don't have control over? Like Mother Nature hurling 40mph gusts at you and your unshielded scope. Or that cloud of mosquitoes that decided to feast on your exposed back. And what are you supposed to do about the fine film of dew forming on your primary?

Errors in judgment will ambush you, too — like using that roll of Kodachrome 25 you've been saving since Dad's birthday for a 45-minute piggyback shot of Sagittarius. Boy, will you be surprised when you get *those* pictures back! You'll feel even worse when you learn it would have performed great on the lovely conjunction that happened at sunset. Next time you'll remember reciprocity failure. Or maybe you're confused about why you got double images and internal reflections of the Moon-Venus pair. Did you forget to remove



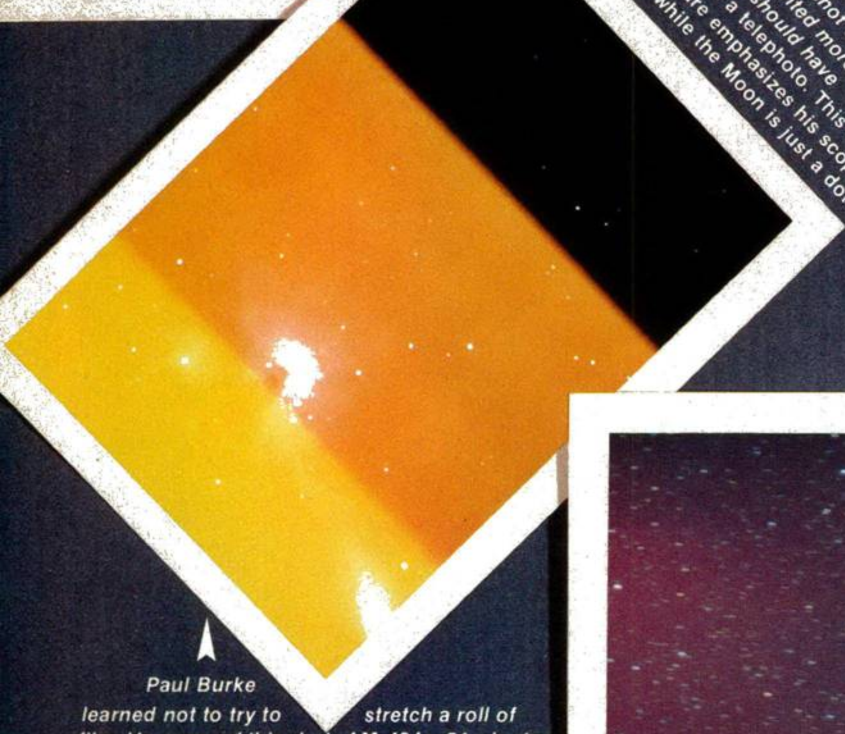
David Rendall discovered it's not a good idea to take star-trail photos in a field filled with fireflies — unless you want out-of-focus yellow streaks in a sharp star-trail image. He exposed Ektachrome 400 for 3 hours through a 50mm f/2 lens.



Michael Covington bumped into his guidescope during a 3-minute exposure, producing double images.

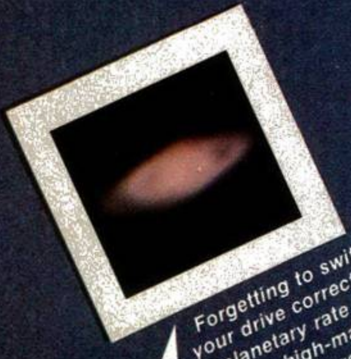
Emery Hildebrand used the wrong lens for his shot of a lunar eclipse. He wanted more magnification and should have used a telephoto. This wide-angle picture emphasizes his scopes — while the Moon is just a dot.

Hildebrand also tried this 60-minute exposure of the Rosette Nebula through a 200mm lens on Ektachrome 400. Unfortunately the exposure was too long and stray sky light fogged his film.

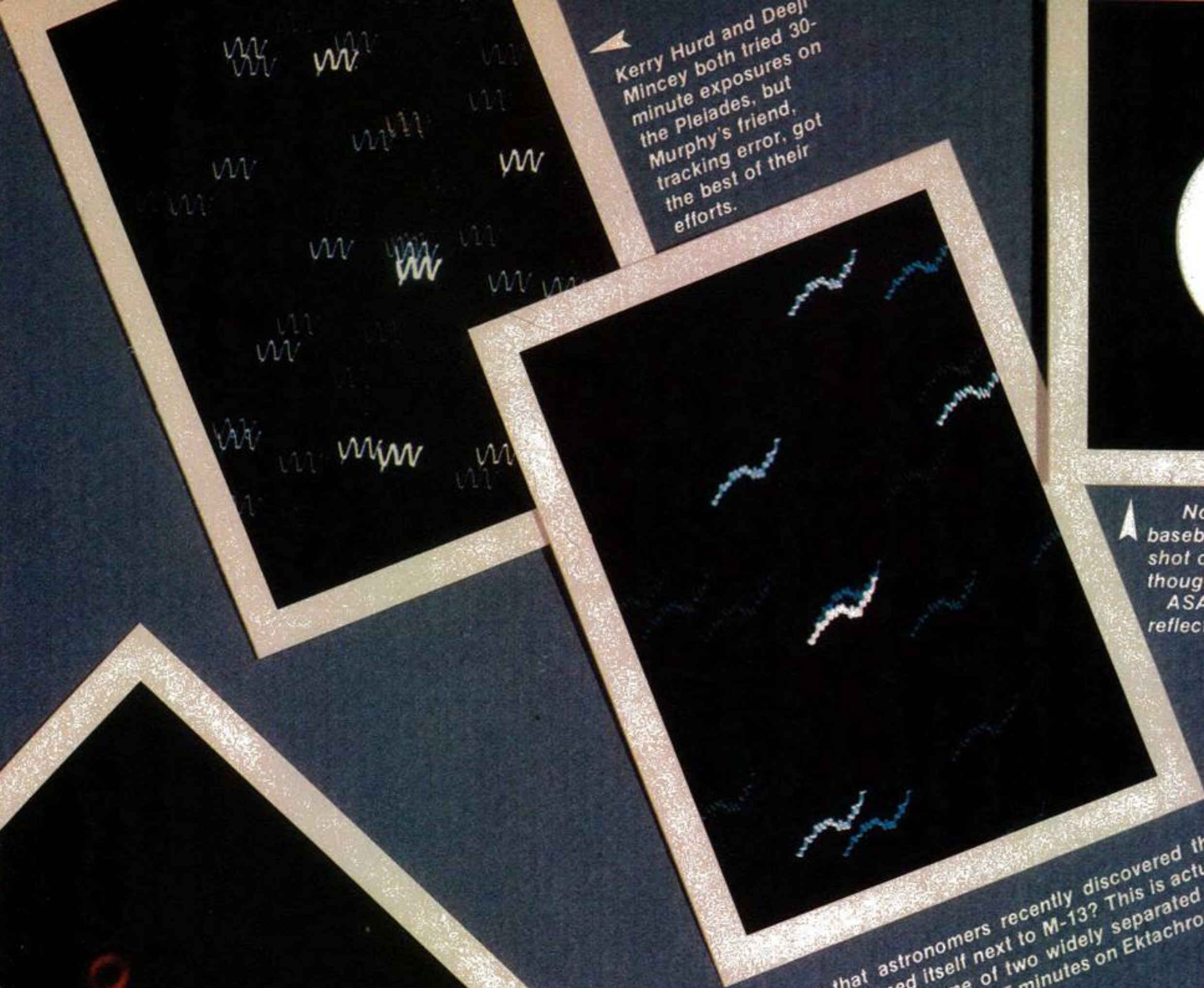


Paul Burke learned not to try to stretch a roll of film. He exposed this shot of M-42 for 54 minutes on the first frame of the roll — but the Orion nebula didn't make it into the picture.

This one has been dubbed "the Brake Light Nebula" and combines four bloopers in one. Some star party member drove off during the exposure, causing the red flares. Dew created the soft-focus effect. The camera sagged a little during the exposure, skewing the trails, and finally — no records were kept!

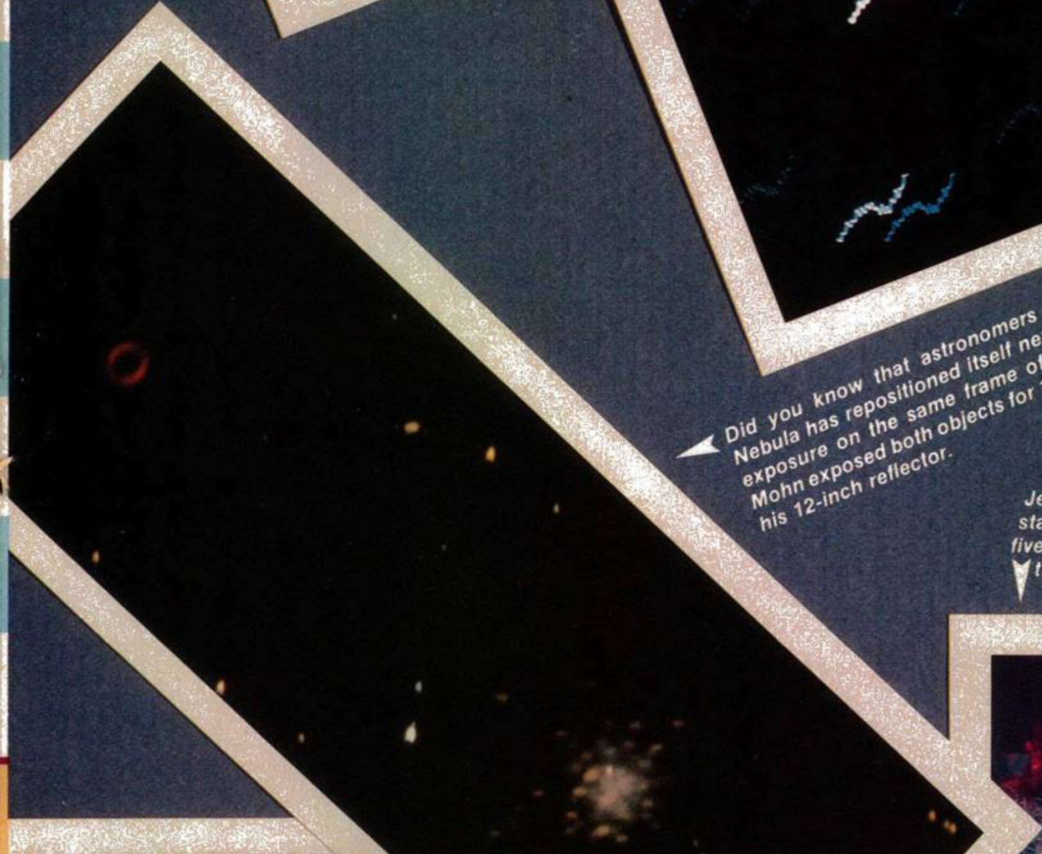


Forgetting to switch your drive corrector to its planetary rate causes high-magnification exposures to trail. This Saturn shot is by Kerry Hurd.



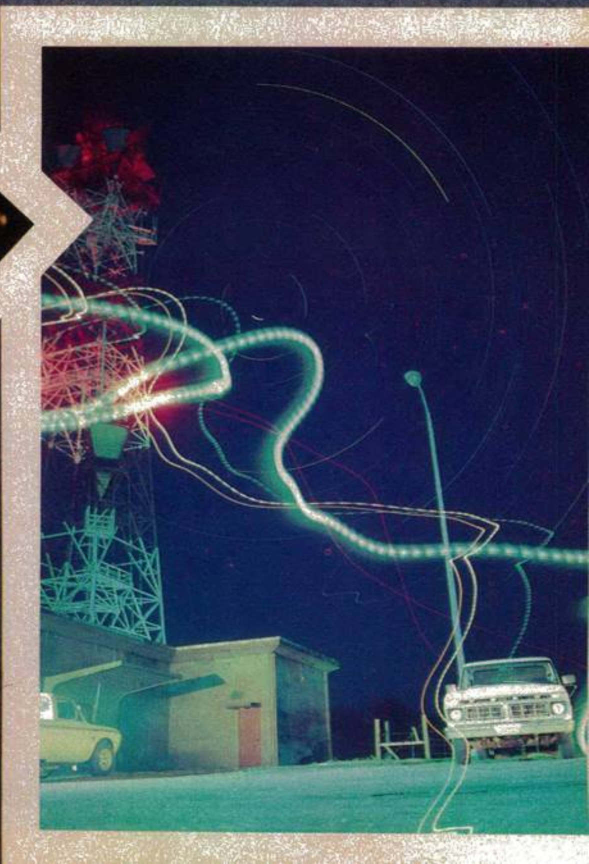
Kerry Hurd and Deeji Mincey both tried 30-minute exposures on the Pleiades, but Murphy's friend, tracking error, got the best of their efforts.

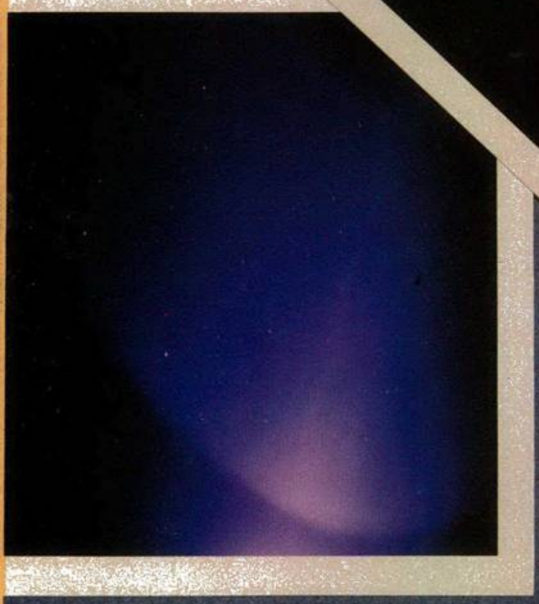
No, this isn't a close-up of a baseball — it's a very over-expose shot of the Full Moon. Brad Shave thought a 1/125-second exposure o ASA 400 through an 8-inch f/6 reflector might be right — it wasn't



Did you know that astronomers recently discovered that the Ring Nebula has repositioned itself next to M-13? This is actually a double exposure on the same frame of two widely separated objects. Allan Mohn exposed both objects for 15 minutes on Ektachrome 400 through his 12-inch reflector.

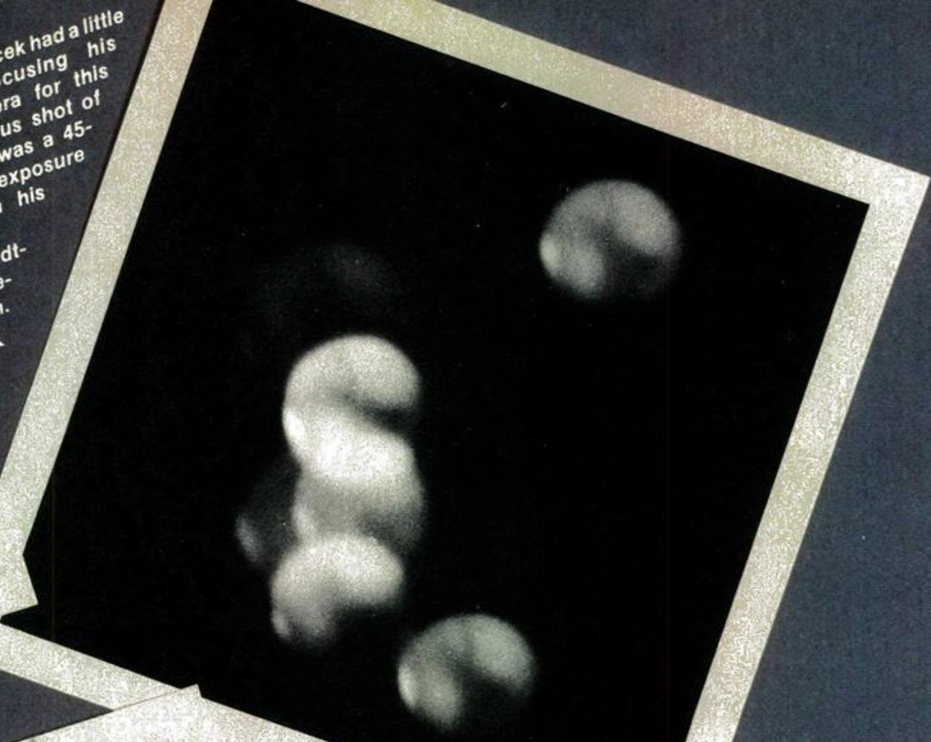
Jeremy Spencer wanted to take a long-exposure star-trail photo, but he ran into trouble during the five hours he had the lens open. Several cars drove through the field of view while his camera was mounted in a parking lot.





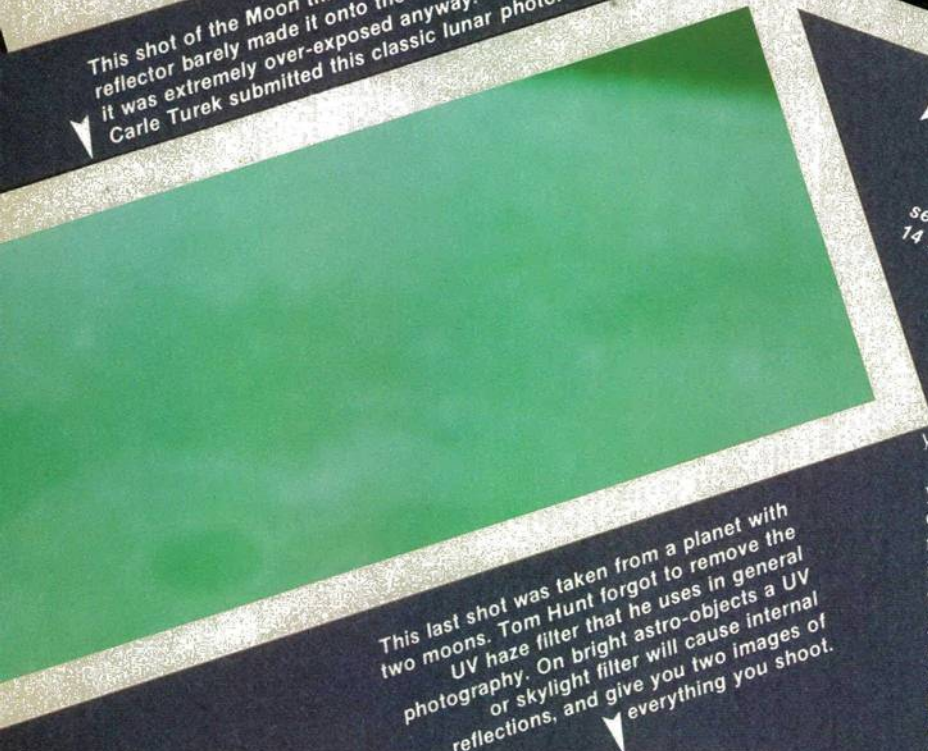
George Roussos found out what happens when stray light finds its way into the lens — ghost-like flares result. This shot was perfect except for the flare and the fact that he doesn't know what section of the sky it is.

John Dvoracek had a little trouble focusing his SLR camera for this prime focus shot of M-27. It was a 45-minute exposure through his 8-inch Schmidt-Cassegrain.

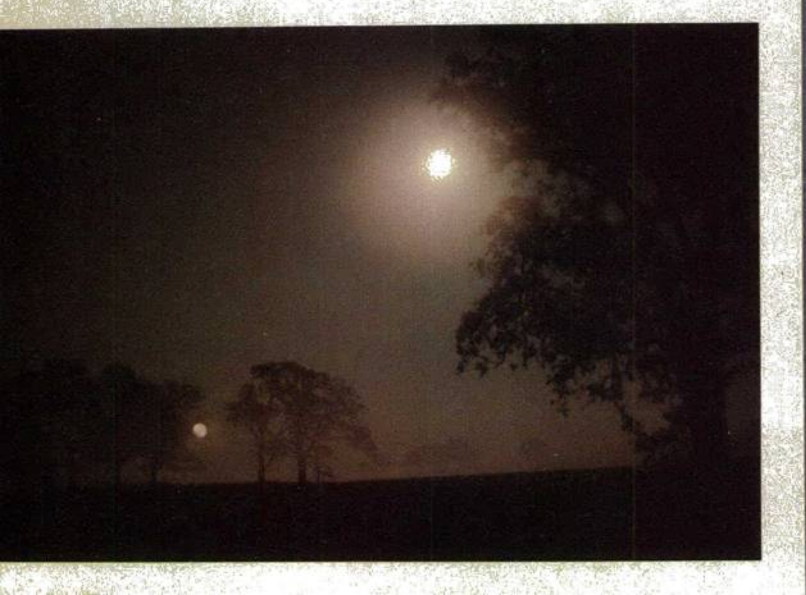


Although it is a good idea to position more than one planetary image per frame, Ken Owen got a little carried away with these shots of Mars. Actually he said his film didn't engage on the sprocket. The exposures were three and six seconds through a 10-inch reflector on Adox KB-14 film.

This shot of the Moon through a 6-inch reflector barely made it onto the frame, but it was extremely over-exposed anyway. Carle Turek submitted this classic lunar photo.



This last shot was taken from a planet with two moons. Tom Hunt forgot to remove the UV haze filter that he uses in general photography. On bright astro-objects a UV or skylight filter will cause internal reflections, and give you two images of everything you shoot.



your skylight filter?

And remember how the first roll of pictures you took with your brand-new $1000 telephoto developed into stars that looked like fuzzy tennis balls. Did you forget to reset the focus to infinity? Another roll of film bites the dust. And what about the time you sent those 36 frames of Jupiter — eyepiece projected for image scale, and oh-so-carefully guided — off for developing, and your film came back blank? Did you check to make sure the film was going through the camera? "Oh no," you groan, "I was in such a hurry. . ." Say no more; just be more careful next time.

And speaking of developing: Have you ever got back a roll of film with all 36 shots sliced neatly down the middle? Those automatic frame cutting machines can't tell where your astrophoto begins or ends — so they just randomly cut 'em up. Too bad, though, there wasn't anything else wrong with them. Maybe you should try developing your film at home. But getting the film on the reel could put you in an institution. And all those smelly chemicals are either too hot or too cold. Better make sure you have a good thermometer — not the one in the medicine cabinet.

But take heart; you will learn to anticipate and correct many of these problems. Our thanks to all the courageous astrophotographers who sent us their bloopers.

— *Berry Brunk*

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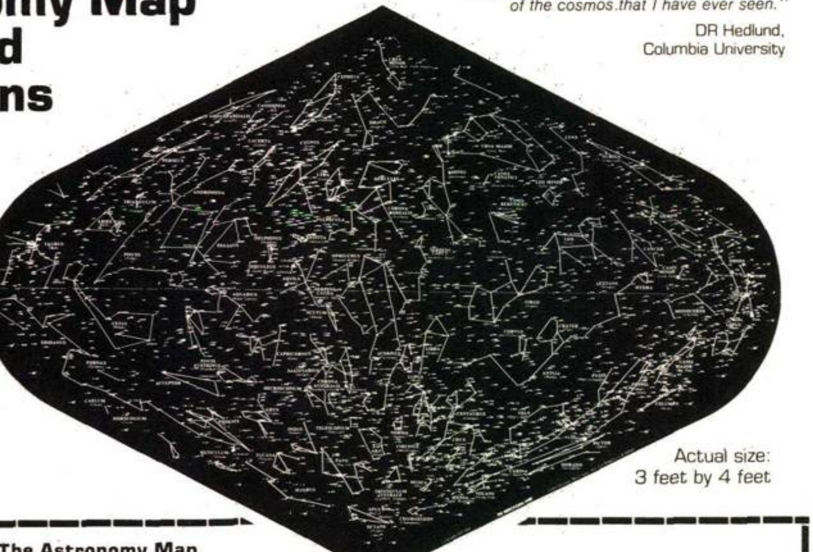

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ASTRONOMY
REVIEWS

Cosmic Discovery

Martin Harwit
334 pages, hardcover, $25.00
Basic Books (1981)

Asked to rank consecutively the important astronomical discoveries of all time, most astonomers would begin the list in antiquity with observations of naked-eye stars and conclude with the most recent results of non-optical astronomy. And if you charted a graph of these discoveries, it would show a steeply rising curve that correlated closely with rapidly increasing technological advances.

Astronomer Martin Harwit bases much of his remarkable book on just such an approach. Spanning 43 basic discoveries, his list commences with observations of stars, planets, and novae, and continues on to conclude with such highly complex and less understood objects as superluminal sources and gamma-ray bursts.

But *Cosmic Discovery* is more than just a history of important astronomical discoveries. In additon to describing those 43 phenomena which could be considered the core of man's knowledge of the cosmos, Harwit examines astronomical discovery in terms of the broad spectrum of political, financial, and sociological implications.

This leads him into interesting areas not often touched upon. For example: How many more major discoveries await us? When is it most likely that such discoveries will take place? What are the roles of industry and the military in the unveiling of new astronomical knowledge? Are the present systems of peer review and shared time on the nation's largest telescopes really conducive to producing new knowledge? Is the way astronomical research is funded helpful or harmful to the search for knowledge?

Harwit probes the ways and means of astronomical discovery keenly and critically. He stresses that investigative modes and the complexities of observational conditions can confuse the gathering of data. Since knowledge and data come to us through various "windows" (channels of the electromagnetic spectrum), decisions must be made regarding what elements constitute a discovery and how such a discovery might differ when observed through a different window.

Astronomical objects or phenomena can be recognized in several overlapping ways. Before you announce the discovery of a new entity in the cosmos, you have to consider carefully the mode of observation. You might simply be observing something already known — but through a different window that gives you a changed perspective. Harwit even provides a device not unlike a botanist's key by which an investigator can "key out" the phenomenon under investigation and determine if indeed it is a new discovery.

This leads to the question of just how many truly different phenomena there are in the universe. Although it's difficult to estimate all phenomena which could make up the universe, the author's (perhaps overconfident) expectation is that after all suspected phenomena have been detected, recognized, and classified, we could then logically determine what remains out there awaiting discovery. Harwitt mentions three such possibilities: disk stars, black holes, and intelligent life.

He points out the paradox that astronomy is one of the most exciting sciences at the same time it is the most constricted of all in its data gathering. Astronomers cannot control sources of information as do laboratory experimenters. They can't even ask questions of the universe in the same sense as other scientists.

Instead, information arrives on Earth in raw form — just as the cosmos produces it. And information comes to us in only five ways: electromagnetic radiation, cosmic ray particles, neutrinos, anti-neutrinos, and gravity waves, so our overall means of accumulating data is comparatively limited.

Interestingly, approximately half of all astronomical discoveries have been made by non-astronomers and nearly half have been fortuitous. Harwit says "theory and observations pursue their own somewhat separate ways, and the major cosmic phenomena continue to be discovered mostly by chance."

The final chapter of *Cosmic Discovery* includes twelve specific recommendations regarding how best to further the future of astronomical discoveries. And of that future Harwit says "a continuing effort must be made to improve our understanding of the factors that lead both to conceptual and observational advances in astronomy. This improvement can come about only through historical and sociological studies conducted at the highest levels of professionalism."

Cosmic Discovery gives an excellent overview of discovery and information processes, and will be of high interest to the pure researcher, whether observer or theoretician. Harwit's book will also interest those who are instrumental in the design aspects of observation as well as those who ultimately control the purse strings of discovery.

This important book illuminates facets of astronomy that for many people have remained shadowy and ill-defined. If you are curious and concerned about the complexities of modern astronomical discovery, you will find it very enlightening reading. *Gail O. Clark.*

Cosmic Dawn
Eric Chaisson
302 pages, hardbound, $14.95
Atlantic — Little, Brown (1981)

In *Cosmic Dawn*, Eric Chaisson compresses and condenses universal history to help us understand mankind's two most perplexing riddles: the origin of matter and the origin of life.

In the first portion of the book, the author lays a groundwork to help readers grasp the incredibly large and small numbers, distances, and objects that will be encountered later in the text. With these foundations established, *Cosmic Dawn* creates a speculative and fascinating story of the universe beginning a microsecond after the Big Bang.

Chaisson discusses the birth of stars and planets at some length, and implies that the formation of planetary systems such as our own is probably a common process. This in turn implies that countless planets may now circle numerous distant suns in our own and in other galaxies. It's a credit to his writing that you won't need a strong knowledge of astronomy, chemistry or biology to understand the processes he describes.

Midway through the book, Chaisson looks at the Earth and provides an overview of primal conditions and the molecular interactions which resulted in life. A brief excursion into biology and natural selection leads the reader along the complicated path of evolution. The author describes the burgeoning growth of human intellect and how — tempered by climate, the discovery of fire, and the development of language and writing — the Earth's highly complex and varied cultures arose.

Looking to the future, *Cosmic Dawn* makes the point that earthly life will probably survive its present crises but eventually will face the "Last Crisis" when the Sun becomes a red giant and expands to engulf the Earth. Prior to this vastly distant event, however, Chaisson sees more immediate barriers to survival which inhabitants of Earth must surmount, including overpopulation, self-destruction, and subjugation by computers.

Overpopulation and self-destruction are long-familiar themes, underscored by the exponential growth of humanity and the existence of the nuclear equivalent of five tons of TNT for each human on the planet. Chaisson's speculation that the next evolutionary step beyond *Homo sapiens* might be a silicon-based computer — he calls it *Fragmentum silicus* — is a little unsettling.

The book is easy to read and sufficiently engrossing to ensure a front-to-back reading in very few sittings. A few stylistic inconsistencies, however, seem out of place. For example, following a cogent discussion of the supernova which produced the Crab Nebula, Chaisson wryly observes, "Numerous other massive stars no doubt vomited in earlier times." The image grates. Similarly, referring to intellect and intelligence as "basic smarts" stands out uncomfortably. These are verbal formulas that may add color to a lecture, but come across inappropriately on the printed page.

Quibbles aside, any reader who enjoys contemplating the processes which produced matter and life as well as black holes, quasars, and similar exotic constructs will find a heaping measure of cerebral stimulation in *Cosmic Dawn. Gail O. Clark.*

The Coattails of God
Robert M. Powers
288 pages, hardcover, $15.95
Warner Books (1981)

To the generations who have grown up with Mr. Spock and Luke Skywalker, the idea of mankind streaking through the Galaxy may

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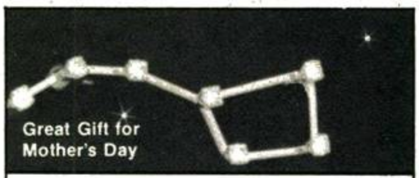

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seem nothing more than an obvious extrapolation of the technology that brought us the Apollo Moon landings and *Columbia*.

But it is more than that — much more. For convenience in making a good story, science fiction presumes advances which we have no way of predicting and which might very well never happen. If interstellar spaceflight ever becomes a reality, there's good evidence it still won't become a commonplace activity.

The Coattails of God attempts to tie together several arguments and show that starflight is indeed possible. The book discusses a number of topics such as the "light-barrier" and whether it can be overcome, power sources, design of self-sufficient spacecraft for long duration flights, suspended animation, the social organization of the crew, space materials processing and building of gigantic ships, and the likely destination for initial missions.

As are his two previous books, *Planetary Encounters* and *Shuttle*, Powers's new work is a compilation of thoughts and speculation from many sources. But unlike them, *Coattails* deals with the not-yet-real, and the author's consequent inability to clothe his ideas in specifics left this reader somewhat less than satisfied.

Much of the work is choppy and disjointed. Chapter 4, "No Way To Beat The Dealer?", a discussion of possible ways to circumvent the speed of light barrier, seems especially rough. Here and in many areas of the book, specific information is gratuitously inserted without explanation. On page 109, where the author discusses habitable planets for man, this problem becomes obvious:

"There could be planets in which only a narrow belt would be habitable. A world with a high equatorial inclination might have a belt between 14° N and 14° S where conditions are good for mankind."

Where did the figure of 14° come from? No doubt, the original researchers whose work is being paraphrased had their reasons for choosing it, but Powers owes his readers a little more explanation. This is only one of numerous examples in which specific information is baldly inserted.

A thorough discussion of the British Interplanetary Society's Project *Daedalus* — a well-thought-out design for a starship — would have been much more valuable than the rehash of material on space mining and space colonies found in the chapters entitled "The First Step" and "A Stately Pleasure Dome." Unfortunately, although *Daedalus* and several other starcraft are briefly discussed, references to them are scattered and incomplete.

Illustrations, too, are lacking — other than a few uninspiring black and white renditions of otherwise excellent art by Ron Miller. Particularly wanting are diagrams and cutaways of the *Daedalus* starship and Powers's own design, *Agamemnon.*

The Coattails of God is worthwhile reading for anyone interested in the long-range future of space exploration, but it lacks the enthusiasm and excitement of Powers's first two books. Measuring the book's faults against its price, a prospective reader would do best to wait for the paperback version. *Larry Sessions.*

Our Turbulent Sun
Kendrick Frazier
198 pages, hardcover, no price given
Prentice-Hall (1981)

Writing for the layman, Frazier explains the current state of our knowledge of the Sun: its structure and basic properties, past behavior, and what it may do in the future.

Investigating the Universe
F. D. Kahn, ed.
458 pages, hardcover, $54.50
D. Reidel (1981)

It is a European academic custom — on the occasion of someone either retiring or reaching a suitably advanced birthday — for his students and coworkers to prepare a volume of articles on topics which his work has greatly advanced, and to "present" them to him. Such a volume is commonly called a *Festschrift.*

Investigating the Universe is a *Festschrift* in honor of Zdenek Kopal's retirement. Kopal (*b.*1914) has long been active in several fields of astronomy, including close binary star systems, solar system and galactic dynamics, and the hydrodynamics of gas flows. This volume contains 14 articles written at a professional level. In many cases, the authors have prefaced them with personal reminiscences of Kopal.

Archaeoastronomy in the Americas
Ray A. Williamson, ed.
405 pages, paperback, $19.95
Ballena Press (1981)
[publisher's address: 381 First St.,
Los Altos, CA 94022]

The 28 papers in *Archaeoastronomy* were presented at a conference in 1979. The book is divided into five sections: the role and development of the discipline, North America, Meso-America, South America, and, somewhat incongruously, Europe.

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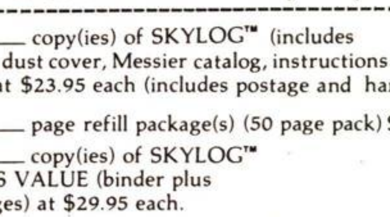

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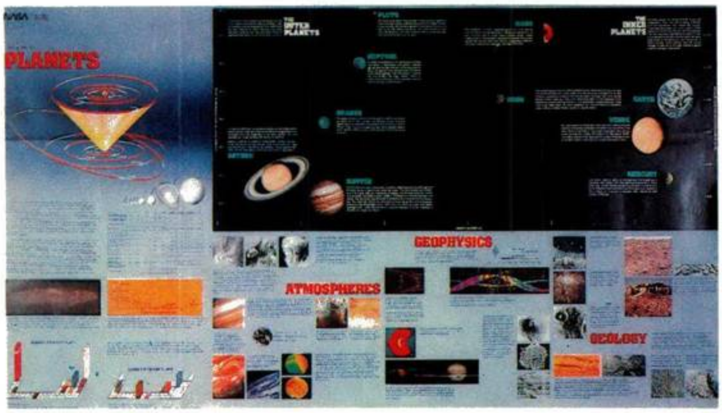
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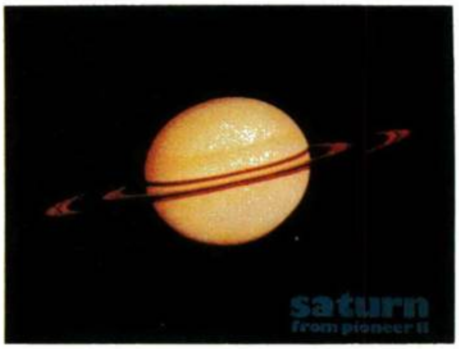
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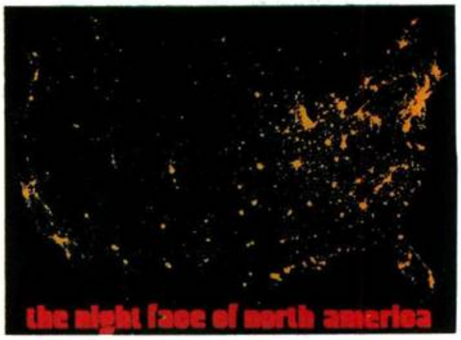
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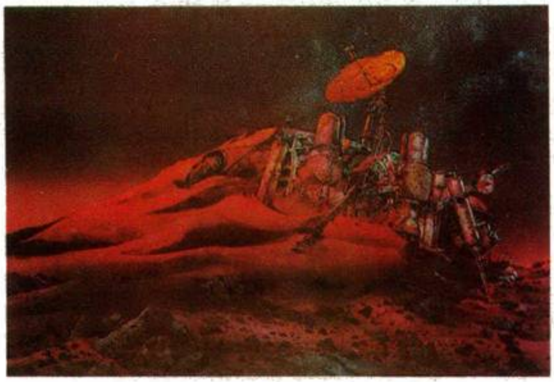

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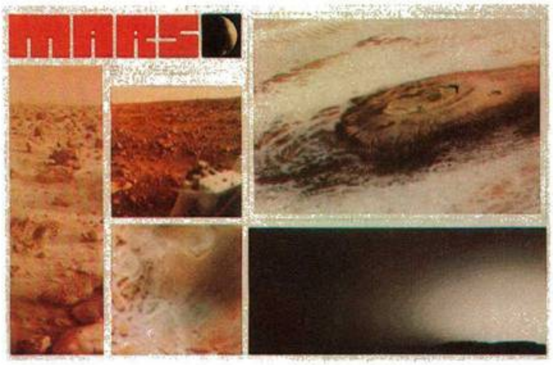

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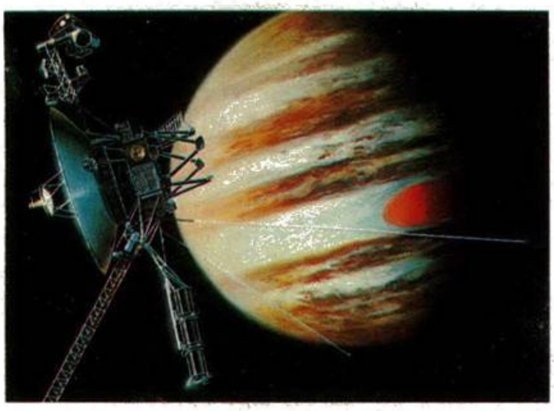

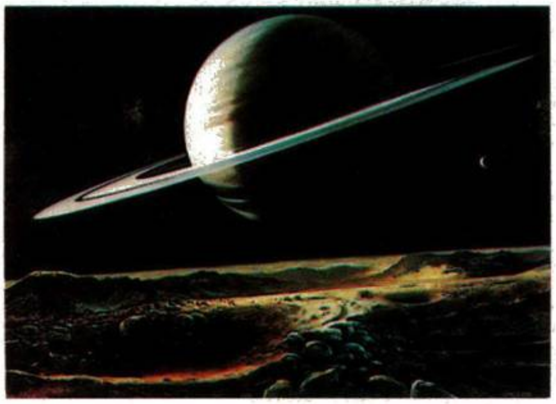

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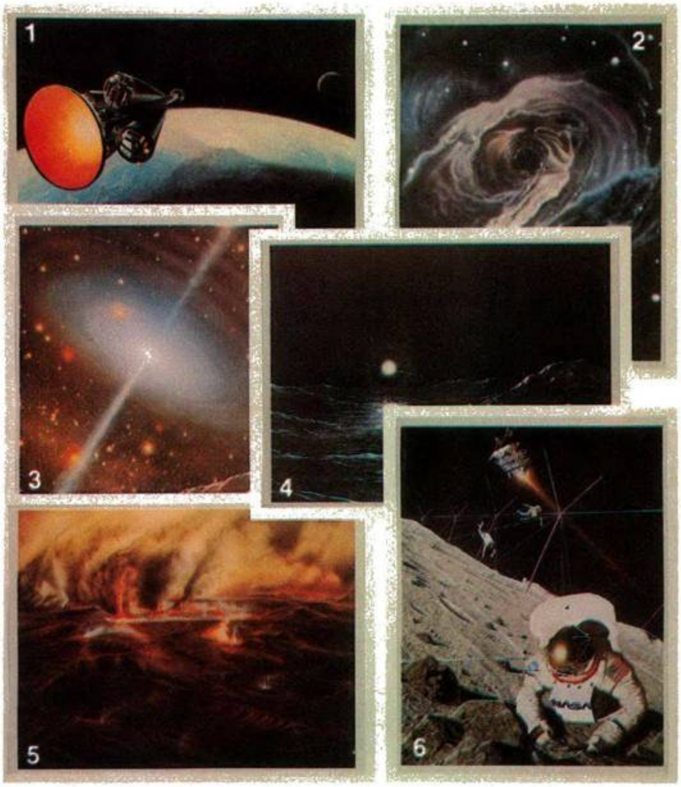

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alt-azimuth setting circles

equipment atlas

by Paul Burke

Is that M-11? M-22? Or have you, Johnny Palomar, just discovered your first comet? Maybe you have, but you'll never know, because you haven't a clue where that scope is pointing. Oh, well. That's how it goes, right? After all, it's only a Dobsonian, and everyone knows you can't get positions from an alt-az. At least, not without getting into all those ascensions, declinations, nutations, elongations, and a whole ocean of other-tions you've heard about and dreaded.

And so Comet Palomar passes on to become Comet Someone Else — all because of those "can't be dones" you listened to.

Well, it *can* be done. To start with, setting circles are not difficult to put onto any alt-azimuth mounting. Take a look at your camera tripod — it may already have a usable set of scales attached to its elevation and rotation axes.

Using just these scales and a few calculations, I followed Jupiter and Saturn all year long *during daylight* with 11 x 80 binoculars, cameras, and a C-90 — each mounted on a simple camera tripod. With this same set-up, it was easy to get a good-enough north alignment in the afternoon to begin a more precise polar alignment well before sunset. (See the box on page 73.)

There's nothing mysterious or difficult about it. Anyone can do it — and here's how. You need three things: graduated scales, a calculator that handles trig functions, and a few equations.

The first job is to make two scales — one for elevation, the other for azimuth (direction). For elevation, you need only a segment of a circle covering 90°; zero, of course, indicates level. Make it as big as possible without interfering with the rest of the mount. A large drafting protractor — one about 10" or 12" diameter — used as-is will do, or you can scale from it to lay out either a larger or smaller version. Mount it on the elevation axis and take some pains to fix it precisely. A bubble level from a hardware store will make re-leveling "in the field" easy.

For the azimuth circle, you'll need to lay out an entire circumference — 360°. Circular protractors are available in art-supply stores, and once again, can be used either as-is on a small mounting or as the guide for a larger home-built version. In any case, make this scale as big as you can, because large scales can be made and read more precisely.

When you know just how large a circle you can install, multiply the diameter by 3.1416 (π) to work out the circumference. Dividing the circumference by 360 will tell you how far apart each degree line will be. At this point, you may have to trade off some accuracy for ease of construction.

For example, on a 10" diameter base, each degree line falls only 0.087 inch from the last — difficult to see and a chore to mark precisely. On the other hand, marking only every tenth degree will place the lines 0.87 inch apart and you'll lay them out ten times faster. For a 20" base — that of a medium-size Dobsonian — the marks for each degree will lie 0.175 inch apart — not too difficult to mark by hand.

Or you may want to try the commercial approach. Look in a hardware store for a replacement tape for a 3 foot or longer tape measure that's graduated in *tenths* of an inch. Wrap this around a base that's 11.46" in diameter, and you'll have your scale in degrees.

In any case, you'll soon see what works best for your scope and mount. The azimuth base on my camera tripod is only 2.3 inches in diameter, so marking each degree would mean putting down lines only 1/50 inch apart! Consequently, I marked only every 15° and this has proven

Helix Nebula by Alfred Lilge

Lagoon Nebula by Alfred Lilge

adequate for use with binoculars. On the other hand, if you have a Dobsonian telescope, you probably have a large base plate and sizable side bearings; in this case, finely-divided circles make a lot of sense.

Next, you'll need a calculator. Even a plain old "4-banger" will work, though looking up all the sines and cosines in a trig table will eventually drive you nuts. If you do much calculation in astronomy, you'll want — as a bare minimum — a machine that can compute trig functions. One that can also convert between hours/minutes/seconds and decimal hours with the push of a button is very handy. And a machine you can program, be it calculator or computer, makes life very nice indeed. But whatever you use, remember to work slowly at first until you develop the knack. Speed and short-cuts will come with practice.

On to the equations: the first number you'll need is local sidereal time. Since the celestial day is nearly 4 minutes shorter than the 24-hour day our clocks indicate, civil and sidereal time agree only once a year (in September). The difference between the two increases steadily at a rate of 3 minutes 56 seconds per day until it adds up to 24 hours — and the clocks agree again.

You could figure local sidereal time by counting days elapsed from last September 22, adding 24 hours 3 minutes 56 seconds for each day. You'd then add the local standard time to the last day to get local sidereal time. But this is messy and inaccurate, and you have to keep track of days of the year in two different years between January and September.

The better approach is to reckon local sidereal time from January 0 of the current year, keeping track of the days elapsed in this year only. The "day-number" is available from several sources, one of which is your desk calendar. Most of them will have, say, July 2, 1982 listed as day 183. You could also count up the days in each elapsed month: 31 + 28 + 31 + 30 + 31 + 30 + 2 to get 183.

Or you could simply evaluate our first equation:

$$\textbf{Day number} = [275 \times \text{month \# } / \ 9] \\ -2[(\text{month \#} + 9) \ / \ 12] \\ + \text{day of month} - 30$$

The parts between the square brackets [ ] will seldom come out as whole numbers, but that doesn't matter because we'll throw away all numbers to the right of the decimal point. Square brackets mean "take the integer of" the number inside the brackets. For July 2, the first two terms compute as [213.888]-2[1.333]. This simplifies to 213-2, or 211. Finishing the equation, 211 + 2 - 30 = 183: the same day number that the desk calendar gave.

Remember to end the number at the decimal point — don't round it off or you'll get a wrong answer. For leap years, drop the 2 out of the second term.

The day number then fits in this equation:

$$\textbf{GMST} = K + (0.0657098232 \times \text{day number})$$

This gives the mean sidereal time, at 0 o'clock on any day, at Greenwich, England. Why Greenwich? It's the universally recognized point of origin for all astronomers. The value of K changes annually; those for each year until the turn of the century are given in the box on the next page.

Now, we need to add a term to the preceding result to get the sidereal time at the time of day we observe. After all, 0 hours at Greenwich is afternoon or evening in the Americas. This alters the equation to:

$$\mathrm{GMST} = K + (0.0657098232 \times \text{day number}) + (1.0027379093 \times \mathrm{UT})$$

Putting in the term for UT gives us the sidereal time at any time of day, but this still assumes we're at Greenwich. Scattered in different longitudes across North America, we need one more term to correct for our longitude difference and thus give our own local sidereal time:

$$\mathrm{LST} = \mathrm{GMST} - \text{longitude (in hours)}$$

GMST is in decimal hours, but the longitude of your observing site will be in degrees, minutes, and seconds — for example, 78°15′32″ west. You'll first have to change longitude to decimal degrees and then to decimal hours, to match GMST.

Don't know the longitude of your site? Go to your public library and look it up on the appropriate U.S. Geological Survey topographic map. This will provide you with both longitude and latitude, another figure you'll need later.

Convert your longitude into decimal degrees by dividing seconds by 3600 and minutes by 60, and then adding them both to degrees. In the example, 78°15′32″ will become 78.2589°. To complete the transformation, divide by 15 to get decimal hours — here, 5.2173 — and then put the figure into the LST formula.

This tells you *where* you are and *when* you are. What you need next is to find out where to point the scope to find something. Take the quantities just determined — local sidereal time, longitude, and latitude — and look up the right ascension and declination of the object.

Both right ascension and declination will have to be in decimal degrees before you can use them. Converting declination is straightforward, but since right ascension is conventionally expressed in hours, minutes, and seconds of time, you have to convert it first to decimal hours and then multiply by 15 to get decimal degrees.

When you plug these quantities into the next three equations, out will come the two directions to look for the object: altitude (elevation) and azimuth.

The first equation yields hour angle — the difference between your local sidereal time and the right ascension of your object. To keep the units the same, you have to convert local sidereal time to degrees, just as you did with right ascension.

$$\mathrm{HA} = \mathrm{LST} - \mathrm{RA}$$

(Alternatively, you can work with both LST and RA in decimal hours. The result then is the *hour angle* expressed in decimal hours. After subtracting, convert the result to degrees by multiplying by 15.)

We take the hour angle in decimal degrees and plug it and the sines and cosines of some of our other numbers into the next equation. This will give us the altitude of the object above the horizon as seen from our location at the time specified.

$$\sin A = (\sin D \sin L) + (\cos D \cos L \cos \mathrm{HA})$$

D stands for declination, L for latitude, and A for altitude.

Crunch those numbers through your calculator, take the inverse sine of the result, and that's it — the altitude of your object in degrees. If the result comes out negative, the object you selected isn't visible from your location at that time. (Purists please note: the formula ignores refraction.)

One more equation and we're done. To get the azimuth (Az) for the object, the equation is:

$$\cos \mathrm{Az} = \frac{(\sin D - (\sin L \sin A))}{(\cos L \cos A)}$$

Since this equation uses the result of the first, it must be done after it. Take the inverse cosine of the result and you have the true azimuth for pointing your scope — except when the hour angle is a positive number. In those cases, subtract the azimuth the formula gives from 360° to find the true azimuth. North has an azimuth of 0°, east 90°, south 180°, and west 270°.

That's all there is to pointing an alt-azimuth mount to any object. If you calculated correctly, your target will be where the equation says it is.

But to make sure everything's clear, let's run through a sample computation. Assume we're at Palmdale, California, on December 12, 1982 at 9 p.m. PST. We want to know where Betelgeuse will be.

$$\begin{aligned}\text{Day number} &= [275 \times 12 / 9] - 2[(12 + 9)/12] + 12 - 30\\ &= [366.667] - 2[1.75] - 18\\ &= 366 - 2 - 18\\ &= 346\end{aligned}$$

Annual "K" Values

1982	6.62240808	1989	6.64242696	1996	6.59673600*
1983	6.60649392	1990	6.62651304	1997	6.64653192
1984	6.59057904*	1991	6.61059792	1998	6.63061704
1985	6.64037496	1992	6.59468400*	1999	6.61470312
1986	6.62446008	1993	6.64447896	2000	6.59878800*
1987	6.60854592	1994	6.62856504		
1988	6.59263200*	1995	6.61265112	* leap years	

Finding North in Daytime

You're out at your Pavement Narrows viewing site, and you don't know which way is north. Polaris is no help, because it's 10:00 a.m. — broad daylight — and you're setting up to see Jupiter as it culminates in a bright blue sky. There aren't any mossy trees around either.

Here's what you do. Run through all the equations using a UT about 5 minutes from now. Work out all the stuff and note the altitude and azimuth. Level your mounting and adjust your altitude setting to the required value. Guesstimate where south is and align your azimuth circle.

Now sweep carefully in azimuth toward the value your equations gave. With a little searching and a low-power eyepiece, you'll find your object. When the UT you calculated for arrives, quickly set the azimuth scale to read the computed value. Your north alignment is now complete. You can also use the Sun to align your azimuth circle, but be very careful not to look into the eyepiece!

Daylight observing takes practice — it's not easy to pick out something through the blue glare of the sky, but it *is* possible. Look for first magnitude stars or the more prominent planets, Venus and Jupiter. But use some judgment in what you select — don't try for M-1 at high noon. Work out the directions for several stars and pick them up in your scope. Your north alignment will improve as you set up and find several objects.

I use 11 x 80 binoculars and a tripod when I observe from a site I've never visited before. It's easy to pick up some first magnitude star or planet and adjust one leg of the tripod to point north.

Then I set my telescope tripod in the same orientation, pick up the same object, adjust my right ascension circle to the local sidereal time, and start my polar alignment hours before sunset. It saves a lot of time, especially during the short nights of summer. And it's fun to amaze bystanders with a view of a planet or a star in broad daylight!

Crab Nebula by Martin Germano

When we put this into the formula for Greenwich mean sidereal time, we get:

GMST = K + (346 x 0.0657098232)
= 6.622408 + 22.735599
= 29.35800 hours

To add in the term for the time of day when we wish to observe, we must convert 9 p.m. PST to its corresponding time on the 24-hour clock; this comes to 21:00. Then to convert PST to UT, we add 8 hours. Thus, we have a UT of 29:00, which looks silly since it is bigger than 24 hours. But this just tells you that the UT falls in the next day.

GMST = 29.35800 + (29 x 1.002737909)
= 58.4374 hours

Palmdale is at 118°04'48" west — this converts to 7.872 hours behind Greenwich. Its latitude is 34°19'04" north, or, in decimal degrees, 34.3178°.

LST = 58.4374 - 7.872
= 50.5654 hours
(Since this is larger than 24, take off as many 24s as necessary to make the result less than 24.)
= 2.5654 hours
(Multiply this by 15 to change it to degrees.)
= 38.4810

Then look up the coordinates for Betelgeuse, which for 1950 are right ascension 5h 52m 27.8s and +7°23'58" declination. After converting right ascension to degrees, the star's hour angle will be:

HA = 38.4810 - 88.1158
= -49.6348°

This negative figure tells us that the star will be east of the meridian, and the azimuth result, when worked out, will *not* be subtracted from 360.

Now to calculate the altitude of Betelgeuse:

sin A = (sin 7.3994 x sin 34.3178) + (cos 7.3994 x cos 34.3178 x cos -49.6348)
= (0.0726) + (0.5305)
sin A = 0.6031
A = 37.1°

Using this value for altitude in the equation for azimuth, we get:

cos Az = [sin 7.3994 - (sin 34.3178 x sin 37.1)] / (cos 34.3178 x cos 37.1)
= (0.1288 - (0.5638 x 0.6031)) / (0.8259 x 0.7976)
= (-0.2113) / (0.6587)
cos Az = -0.3208
Az = 108.7°

The constants in some of the equations are quite long. Don't worry if your calculator can't handle a ten-digit number, just put in as many as it will hold. Errors due to rounding will be in the arc-second size — well beyond your pointing requirements.

Run the calculations a few times with bright objects — those you can see and check easily — to get the feel of them, and then go on and tackle a few that you would otherwise have to star-hop to locate.

"This is all very interesting," you might be saying by now, "but how does it help me determine the coordinates of Comet Palomar?" — which you just discovered when your loyal assistant knocked the scope off Betelgeuse? There it is, a fuzzy nonstellar object, your ticket to immortality — if only you can tell just where it is.

Positions are simple to find now that you have solved the equations that tell where to point. The exact same equations, with altitude and azimuth substituted for declination and right ascension, will tell you where you are pointed.

Thus, the first equation becomes:

$$\sin D = (\sin A \sin L) + (\cos A \cos L \cos Az)$$

and the second:

$$\cos HA = \frac{(\sin A - (\sin L \sin D))}{(\cos L \cos D)}$$

Now work quickly and read off your setting circles before your LST calculation needs updating. Let's say the azimuth circle reads 117.3° and the altitude 33.9°.

Solving the first equation gives a declination of +0.002°, and the second tells us the hour angle (in degrees) is 47.5245°. Since this is positive, we subtract it from 360 and get a true hour angle of 312.4755°. Convert this to hours by dividing by 15 and use the LST formula (slightly rearranged). You get:

RA = LST - HA
= 2.5654 - 20.8317
= -18.2663 hours
(add 24, since it's negative)
= 5.7337 hours
RA = 5h 44m 01s

Run over to your star atlas and plot your object. By golly, there's something there. M-78 strikes again. (Don't feel bad, it got me, too.)

Anyway, that's how it's done. A little research, a few calculations, and you can point your alt-azimuth scope toward the hard-to-locate denizens of the night sky — in those dim and tenuous nebulae you've had to skip because of the uncertainties of star-hopping.

Your Comet is still out there, but now when you find it, you'll be able to tell the world.

Paul Burke is a research specialist at Lockheed Aircraft in Palmdale, California. He has been interested in astronomy since 1979, and is a dedicated astrophotographer.

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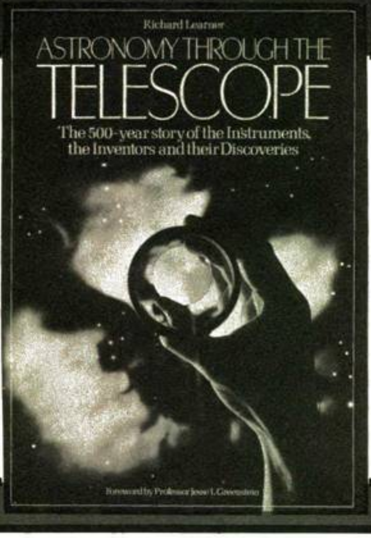
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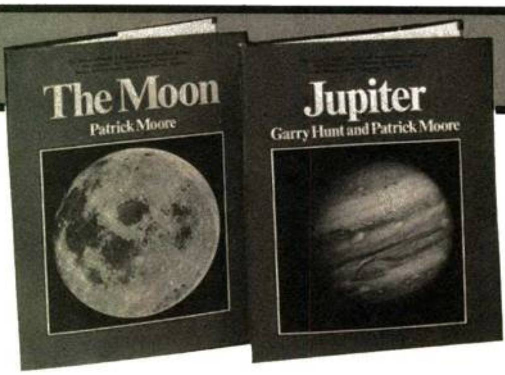

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In fact, at this aperture the domain of the observer encompasses virtually the entire solar system from tiny lunar rills broken by even tinier craterlets, through the bluish-green disks of Uranus and Neptune, to the pinpoint image of Pluto moving from month to month across faint star fields. But the solar system is only a small part of the observer's domain, for at this aperture, globular clusters are so well resolved that each seems to have its own personality. Galaxies are revealed in intricate detail, and even the brighter quasars may be reached.

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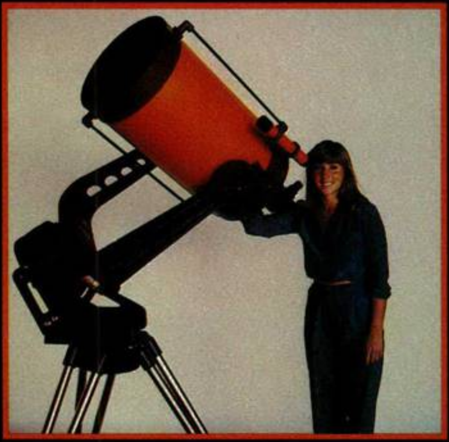

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- both components of the Trifid Nebula are well detailed, with the brighter clearly trisected by dark lanes,
- The Dumbbell Nebula becomes a complete oval with scores of stars apparently embedded in its gossamer beauty,
- the contrast levels of the Ring Nebula are evident, and its central star may be glimpsed occasionally,
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Arc seconds (Dawes' limit)	0.3
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AstroNews

Galileo Mission Saved — Just Barely

NASA has again saved its Galileo Jupiter mission. Last November, the President's Office of Management and Budget (OMB) told the space agency that it planned to cancel the project as part of its general budget cutting.

But at a December 1981 meeting with the White House Chief of Staff James Baker and OMB Director David Stockman, NASA's management reversed the decision by arguing that the few hundred million saved by killing Galileo would mean the end of America's planetary exploration program. The reprieve, however, came at a price: NASA lost funding for the booster that was to send the Galileo spacecraft to Jupiter and for the Venus Orbiting Imaging Radar (VOIR) project, the only other scheduled planetary mission.

Federal frugality and launch vehicle problems have kept the Galileo project in turmoil. When the mission first came up for Congressional approval in 1977, the House wanted to hold down the cost of the space science program and cut Galileo's funding. The Senate, though, supported the project, and the House eventually went along. Since then, attempts to kill Galileo have been a semi-regular part of the annual debate on the space agency's budget.

At the same time, problems with the Space Shuttle and its upper stages twice delayed the launch. Early in the mission's planning, NASA's administrators decided that the Shuttle would carry Galileo into Earth orbit where a three-stage version of the Inertial Upper Stage (IUS) would propel it to Jupiter. Shuttle delays forced the planetary division to abandon the original 1982 launch date and reschedule for 1984. Then the IUS program had large cost overruns, and the space agency decided to use another booster, the Centaur. Launch slipped another year.

These delays combined with the rise in the rate of inflation over the two-year period have raised Galileo's cost from $290 million — a moderate figure as planetary missions go — to $700 million.

NASA believes the project is worth the money. The discoveries made by the Voyager craft as they flew past Jupiter in 1979 showed the promise this miniature solar system holds for planetary science. The Galileo spacecraft will spend 20

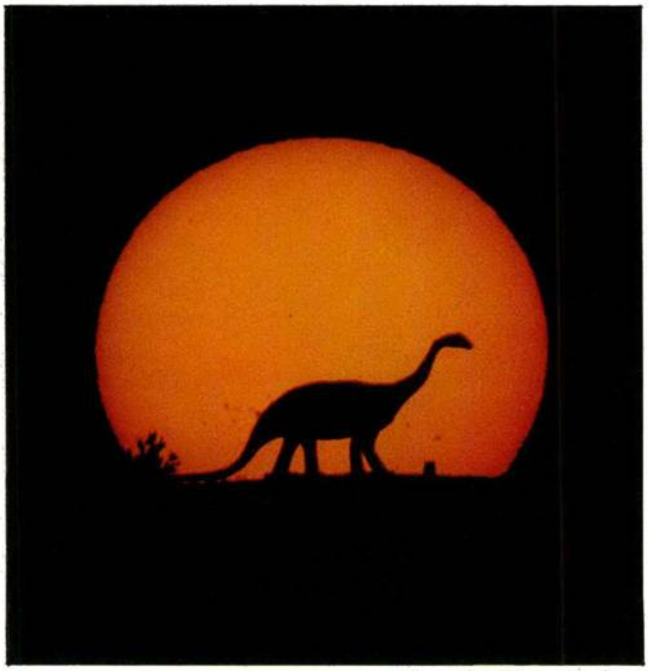


Photo by Glenn Lambert.

Scientists Dispute Theory On Cretaceous Collision

"The Cretaceous went out with a whimper, not a bang." Paraphrasing T.S. Eliot, Dr. Leo Hickey of the Smithsonian Institution and Dr. William A. Clemens of the University of California, Berkeley, have tersely disputed the view that a catastrophe caused by the impact of an extraterrestrial object or the explosion of a nearby star resulted in the mass mortality that brought the Cretaceous Age to an end 65 million years ago.

Hickey and Evans were among 15 scientists speaking at an American Association for the Advancement of Science symposium held in January in Washington, D.C. The scientists presented data on the extinctions of dinosaurs and other Cretaceous life forms.

Evidence for an extraterrestrial disturbance is based on a layer of dust, enriched with rare elements such as iridium, that settled on widespread areas of the Earth at the end of the Cretaceous period.

Two California scientists, Dr. Luis Alvarez and his son, Walter, asserted two years ago that the dust could have been caused by the impact of a giant asteroid. In the Alvarez scenario, the impact would have thrown up an overwhelming dust cloud that would have blocked out the sunlight and stopped photosynthesis, extinguishing life on a global scale. (See months expanding on the Voyager results as it orbits the giant planet and flies past the moons, studies the weather, and explores the magnetosphere. Galileo will also drop a probe into Jupiter's atmosphere to study closely the upper 150 kilometers of the planet's ocean of air.

The space agency has paid heavily to keep this mission. Rising costs have meant it can't afford other planetary missions. Early last year the agency had to cancel its participation in the International Solar Polar Mission and delay several other projects to retain Galileo. Now the loss of the Centaur booster and VOIR in the latest budget cutting will add new costs.

Without the Centaur, NASA must launch the orbiter and probe with a 2-stage version of the IUS, which can't send the spacecraft directly to Jupiter. Galileo instead must follow a trajectory taking it out to Mars' orbit and then back to Earth where our planet's gravity will propel it to its destination. The detour adds two years to the flight. When the craft arrives in early 1990, it will already have been in space for as long as the original mission was to last. The chance that key systems will fail before the mission ends has doubled.

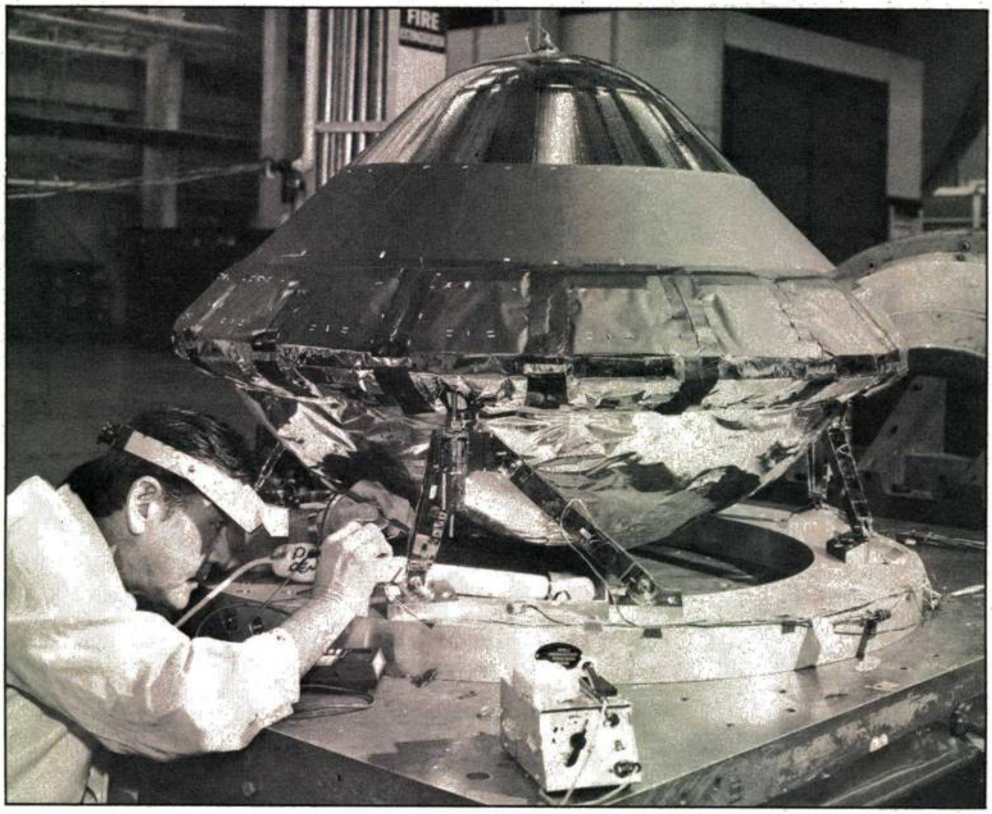
When Galileo reaches Jupiter, its studies of the moons will be halved. The orbiter uses an average of 16 kilograms of fuel to modify its orbit for each close pass at one of the satellites. Now the spacecraft can carry enough fuel for only six satellite encounters instead of the original eleven.

Other studies won't suffer as badly. The probe will enter the atmosphere and make its measurements as planned. The orbiter's studies of Jupiter's weather and magnetosphere will remain largely unaffected although they may be shortened if the spacecraft runs out of fuel early.

The ramifications to the Galileo project of the Centaur cancellation don't end here. The extra two years of mission operations plus some modifications to the orbiter will cost an additional $100-300 million. That could go a long way toward paying for another planetary mission.

Van Kane.

Galileo probe undergoes vibration testing. NASA photo.



"The Fallen Sky," ASTRONOMY, April 1981 and "Asteroid Collisions with Earth," January 1982.)

However, studies by Hickey and Clemens in Montana and Wyoming, with Dr. David J. Archibald of Yale University, contradict this hypothesis. Hickey, a paleobotanist at the Smithsonian's National Museum of Natural History, bases his evidence on the fossil land-plant record at the end of the Cretaceous Age. He emphasizes that his evidence does not rule out a cosmic impact but he contradicts the assertion of overwhelming damage to life on Earth.

"If there really was a sudden global catastrophe," Hickey said, "you would expect mass extinctions of land plants to occur at the same time as dinosaur extinctions. However, in the few places where a complete record is available, such as in the western United States, episodes of dinosaur and plant extinction are separated by an interval of as much as 50,000 to 100,000 years.

"If a catastrophe threw up a vast dust cloud or heated the atmosphere enough to burn off the vegetation," Hickey continues, "the pattern of extinction that resulted among plants should have been relatively uniform around the world. But pollen flora spanning the Cretaceous-Tertiary boundary show no global pattern of extinction and no drastic change in types or abundance.

"The extinctions that occur tend to be moderate in number and geographically restricted. Significantly, the extinction rate is greatest at high latitudes. This is hard to reconcile with the hypothesis of an overwhelming catastrophe because tropical flora are those least capable of survival by means of long-term seed dormancy buds or underground tubers.

"Thus, tropical flora should have been the most damaged by a long period of darkness or subfreezing temperatures caused by a dust cloud. Yet they show the least damage."

If not by a sudden global catastrophe, how did the Cretaceous world end?

In the Hickey-Clemens-Archibald scenario, the twilight of the Cretaceous was brought about by a combination of gradual ecological changes together with long-term climatic cooling first felt nearly two million years before the end of the Cretaceous.

Some forms of life, such as turtles and fish, suffered little change in diversity at the close of the Cretaceous; others, such as corals, dinosaurs and land plants, appear to have gradually dwindled in number until they disappeared completely. Only a few organisms, such as marine algae and some one-celled sea animals, appear to have suffered sudden and widespread extinction directly associated with the mysterious iridium layer at the limit of the Cretaceous. These single-celled organisms are likely to have been more vulnerable to a short-term blackout because as single cells they have less food reserves than terrestrial plants and animals.

Closing their case, with apologies for borrowing and butchering Eliot's lines, the three scientists quote: "This is the way the Cretaceous ended / Not with a bang but extended."

Superluminous Stars Discovered in Globular Cluster

Eleven superluminous giant stars have been discovered in NGC-1866, a young globular cluster in the Large Magellanic Cloud, reports Phillip J. Flower of Clemson University.

The discovery raises to about 40 the number of superluminous giant stars that have been identified in a total of eight globular star clusters in the Large Magellanic Cloud. It also raises the hope that astronomers may be able to determine exactly what a superluminous giant is.

As their name implies, superluminous giants are red or yellow giants that are brighter than normal stars. Those in NGC-1866 are 1.6 times brighter than other giant stars and range in color from white to red. Some astronomers speculate that the giants are merely foreground stars projected by chance against the cluster. But since all 11 stars lie within only 70 light-years of the cluster's core, "it is reasonable to assume that most or all of them are cluster members," says Flower.

Since superluminous giants do not exist in the open clusters of the Milky Way, such as the Pleiades or Beehive, perhaps their existence in the globular clusters of the Large Magellanic Cloud is due to the higher stellar density of globulars. This density is high enough to cause collisions — rare in open clusters, but a fairly likely event where densities are higher. Calculations done on Milky Way globular clusters indicate that more than 3% of all stars near the center of globulars have collided. Collisions will coalesce small stars into larger stars and, possibly, into superluminous giants.

But NGC-1866 poses a problem. Unlike Milky Way globulars, which are all very old, the globular is quite young — only 100 million years old at most — and hasn't existed long enough to have had very many collisions. Only one or two such collisions would have occurred since the cluster formed — and 11 superluminous giants have been observed so far.

Flower proposes that superluminous giants are post-helium-burning red giant stars. According to stellar evolution theory, red giants burning helium are in a very advanced state. When they run out of helium, they collapse and may eject their surface layers, which expand to become planetary nebulae. The central star of a planetary evolves further and dims to become a white dwarf.

Theoretical studies show that stars about to create planetary nebulae should be brighter than normal giant stars and should exist in a wide variety of temperatures. Since superluminous giants have both these properties, Flower says they may be proto-planetary nebulae — stars that have recently ejected their surface layers which will soon form planetary nebulae. *Ken Croswell.*

Centaurus A — Why Does it Broadcast?

For decades, astronomers have puzzled over why some elliptical galaxies like Centaurus A emit huge quantities of radiation in radio wavelengths. One out of ten of these galaxies emits as much energy in the radio region as it does in optical light.

Cen A's proximity enables astronomers to study it more precisely, and their observations are uncovering new pieces of evidence which Kitt Peak astronomer David De Young has put toward completion of the Cen A puzzle.

The first piece of the puzzle is the well-known shape of Cen A's radio source, a shape commonly shared with other radio galaxies. The radio source is not within the optical boundaries of the galaxy and actually is double. The two lobed sources or radio waves are situated on opposite sides of Cen A at right angles to the peculiar dust band and are 160,000 to 200,000 light-years out from the galaxy's core.

But what is the source of the energy which enables these radio lobes to exist? Astronomers have known part of the answer for some time: the radio energy is synchrotron radiation — electromagnetic energy radiated by electrons which have been accelerated to speeds close to that of light and which lose energy as their motion is bent by the magnetic fields contained in the radio emitting regions.

The question narrows to this: How does Cen A generate a continuous supply of relativistic electrons?

De Young has taken note of recent observations, made at the Cerro Tololo Inter-American Observatory, which indicate the presence of fields of massive young stars well outside the optical region of Cen A but within the radio lobes.

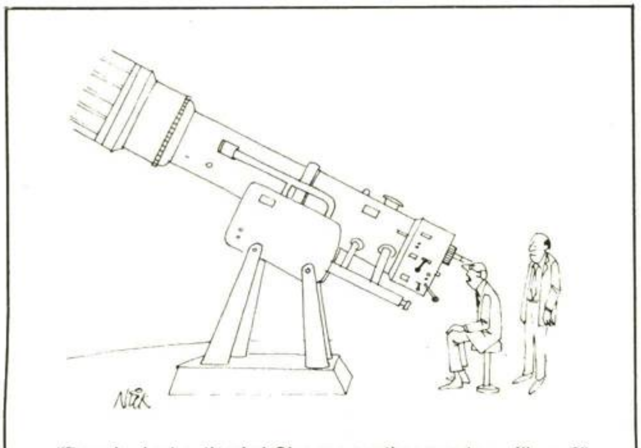
His explanation, based upon these observations, begins with a flattened rotating core of gas deep in the center of the galaxy where material streams out along the poles of the core's rotation — which is in the same plane as the galaxy's dust belt. Material flows out preferentially along the poles because less gas exists there to impede the outflow (the origin of the high pressures inside the core which cause the outflow remains unexplained).

De Young says spectroscopic evidence implies that large amounts of processed material — matter having been at one time in stars and released to the interstellar medium with a greater heavier element content — are "entrained" in the outflow. Entrainment, according to De Young, is the process of the hot gases from the core dragging along this cooler processed matter from farther out in the galaxy. Eventually, as these gases reach distances beyond the visible regions of the galaxy, they cool enough for star formation to begin. De Young's theoretical calculations predict distances from the galaxy's center where this formation will take place that are in agreement with those observed.

De Young also has a theory on where the high energy electrons originate. "Some fraction of them flow out from the galactic core, but we know that they lose energy so rapidly that they cannot still be giving rise to radio emission so many light-years away from the galaxy. Now, a number of the stars formed will be very massive relative to the Sun and because of their mass will burn so intensely that they run through their life cycle rapidly, on the order of 10 million years. When they reach their end, they explode as supernovae. The tremendous energy released during this explosion can re-accelerate the electrons to very high energies. The neutron star that remains after the supernova is also a source of relativistic electrons." De Young's calculations predict the number of supernovae expected, and the resulting energy released is in agreement with that required to power the radio lobes.

Thus De Young's model not only places the origin of the electrons, but also explains why the radio lobes persevere. As long as material is flowing outward from the galaxy's core, massive stars will be formed and supernovae will go off, providing an almost steady source of very high speed electrons.

"When we figure out why material is blasting out from the core, the final piece to the Cen A puzzle will be in place," says De Young.



"Darn budget cutbacks! Give me another quarter, will you?"

Nick Hobart

Private Investors Consider Purchase of Fifth Space Shuttle

Private procurement of a space shuttle orbiter, a potential $1-billion commercial investment, is under final consideration by Space Transportation Co., a subsidiary of a large U.S. investment banking firm. The White House has expressed favorable interest in the idea and NASA is considering the concept.

Space Transportation Co. of Princeton, New Jersey, has been working closely with the Boeing Co. in examining the return on investment from such a procurement. Boeing has been studying the concept since 1978 (*Aviation Week & Space Technology* Oct. 2, 1978, p. 23).

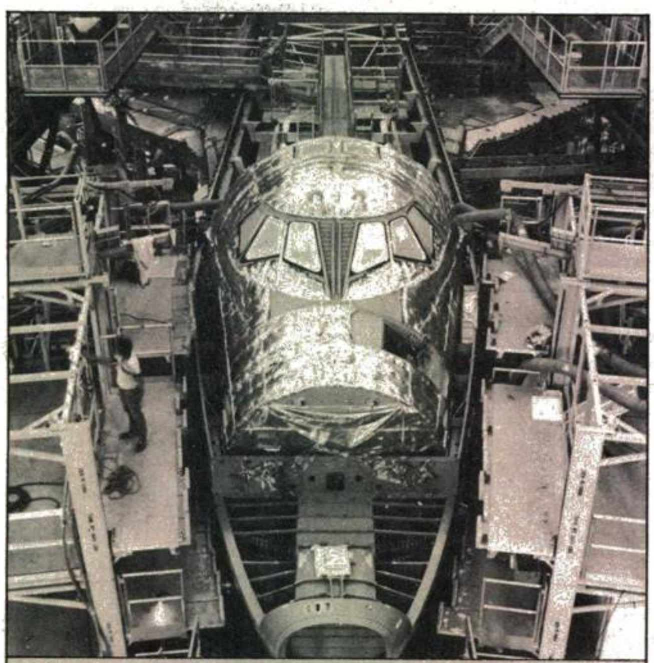
Space Transportation wants to purchase the fifth space shuttle orbiter for operation as a regular part of the existing space shuttle fleet — if the Reagan Administration fails to approve NASA procurement of the fifth orbiter.

White House Science Advisor George A. Keyworth told the officials involved that the idea "dovetails very well with the Reagan Administration's political and economic philosophy." Keyworth was very positive about the idea and encouraged the company to proceed.

NASA has sought funding for a fifth shuttle orbiter for some time and recently began studies to see if a fifth spacecraft could be procured in the Fiscal 1984 budget, possibly as part of a block buy along with a renegotiated contract for Orbiter 104 (*AW & ST* Dec. 21, 1981, p. 12).

Space Transportation Co. has begun to form potential financing partners into a group that could make the early and continuing investment required to fund the approximately $1-billion cost envisioned for a shuttle orbiter.

"We have met with a number of very important institutional investors," a representative of the investment group said. "The financing of a project like this is always a tricky thing. You can point to any number of unusual projects financed in unusual ways like the Alaska pipeline. We have gotten pretty far down the road with a number of potential investors." He stressed, however, that no funding arrangements have been signed yet.



A private consortium of banks and other investors plans to buy the fifth shuttle orbiter produced by Rockwell International. Both NASA and the White House support this venture that heralds the commercial use of space by the American private sector. NASA photo.

AstroCalendar

April 28-30.	**19th Space Congress.** Cocoa Beach Florida. Contact: Melodie de Guibert, P.O. Box 1333, Cocoa Beach, FL 32931.
May 1.	**Telescope User's Clinic.** Contact: Western Observatorium, 13215 E. Penn St., Suite 411, Whittier, CA 90602.
May 1.	**International Workshop on Cometary Astronomy.** Bryant College, Smithfield, Rhode Island. Contact: Richard F. Lynch, 12 Greenbrier Rd., Greenville, RI 02828.
May 9-14.	**The New Astronomies.** Tucson, Arizona. Contact: Selected Studies, A&I 1190A, Smithsonian Institution, Washington, DC 20560.
May 10-13.	**Symposium on Photoelectric Photometry with Small Telescopes.** Auckland, New Zealand. Contact: W.H. Allen, P.O. Box 5526, Moray Place, Dunedin, New Zealand.
May 18-22.	**Saturn Conference** (professional meeting). Tucson, Arizona. Contact: M.S. Shapley, University of Arizona, Lunar and Planetary Laboratory, Tucson, AZ 85721.
May 26-28.	**1982 Annual IAPPP Symposium.** Big Bear, California. Contact J.L. Hopkins, 7812 W. Clayton Dr., Phoenix, AZ 85033.
May 26-30.	**Amateur Astronomy and Telescope Making Conference** sponsored by the Astronomical League's S.W. Region. Fort Davis, Texas. Contact: George D. Ellis, 7117 Misty Meadows Dr. S., Fort Worth, TX 76133.
May 28-31.	**Riverside Telescope Maker's Conference.** Big Bear, California. Contact: Cliff Holmes, 8642 Wells Avenue, Riverside, CA 92505.
June 11-12.	**12th Annual Apollo Rendezvous and Telescope Fair.** Contact: Coordinators, Apollo Rendezvous, 2629 Ridge Avenue, Dayton, OH 45414.
June 26-July 2.	**93rd Annual Meeting of the Astronomical Society of the Pacific.** University of California, San Diego — La Jolla, California. Send SASE to: San Diego Meeting, A.S.P., 1290 24th Avenue, San Francisco, CA 94122.
July 16-24.	**National Spaceweek.** Needs local organizers. Contact: Spaceweek National Headquarters, P.O. Box 58172, Houston, TX 77058.
July 18-August 8.	**International Workshop for Amateur Astronomers** (I.W.A.A.). Havelte, The Netherlands. Contact: Niels van Weersen, Sand-Ambachstraat 17, 2691 BL 's Gravenzande, The Netherlands.
July 21.	**24th Annual Summer Science Program in Astronomy.** Ojai, California. Contact: Roger D. Klauscer, Thacher School, Ojai, CA 93023.
July 21-24.	**ALCON '82** — national convention of the Astronomical League including ALPO, IAPPP, IOTA and National Deep Sky Observers annual meetings. Peoria, Illinois. Contact: ALCON '82, P.O. Box 5203, Peoria, IL 61601.
August 14-17.	**Stellafane.** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Road, Sudbury, MA 01776.

In the enormous emptiness of our local Universe there are one hundred billion stars: A star for each human being that has ever lived! Is there anyone out there...or are we alone? No one knows, but we can begin to look for signs of extraterrestrial intelligence by eavesdropping on the radio communications that they may use.

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- *All $100 or more contributions receive NASA's Report #SP-419 on SETI.*
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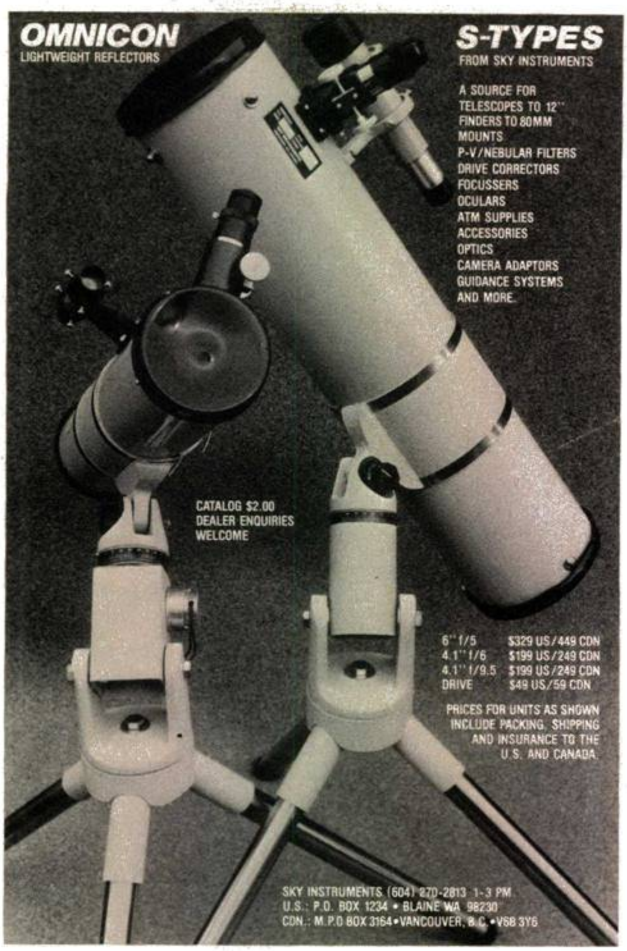

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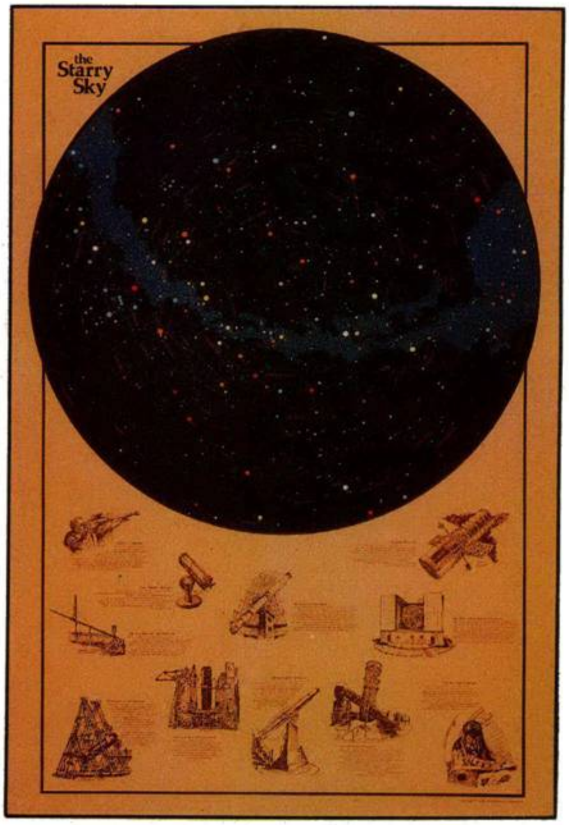

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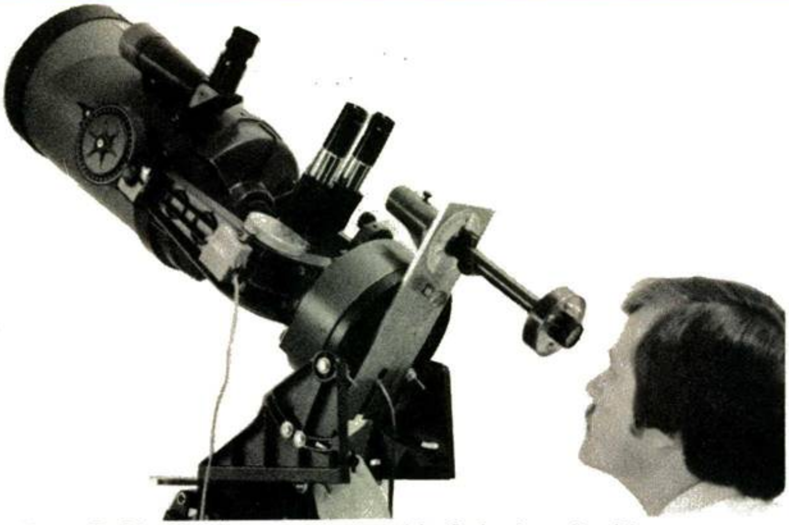

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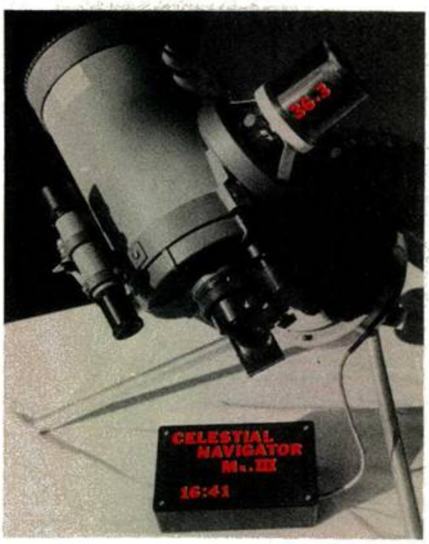

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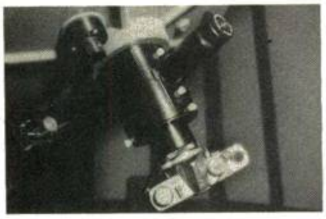

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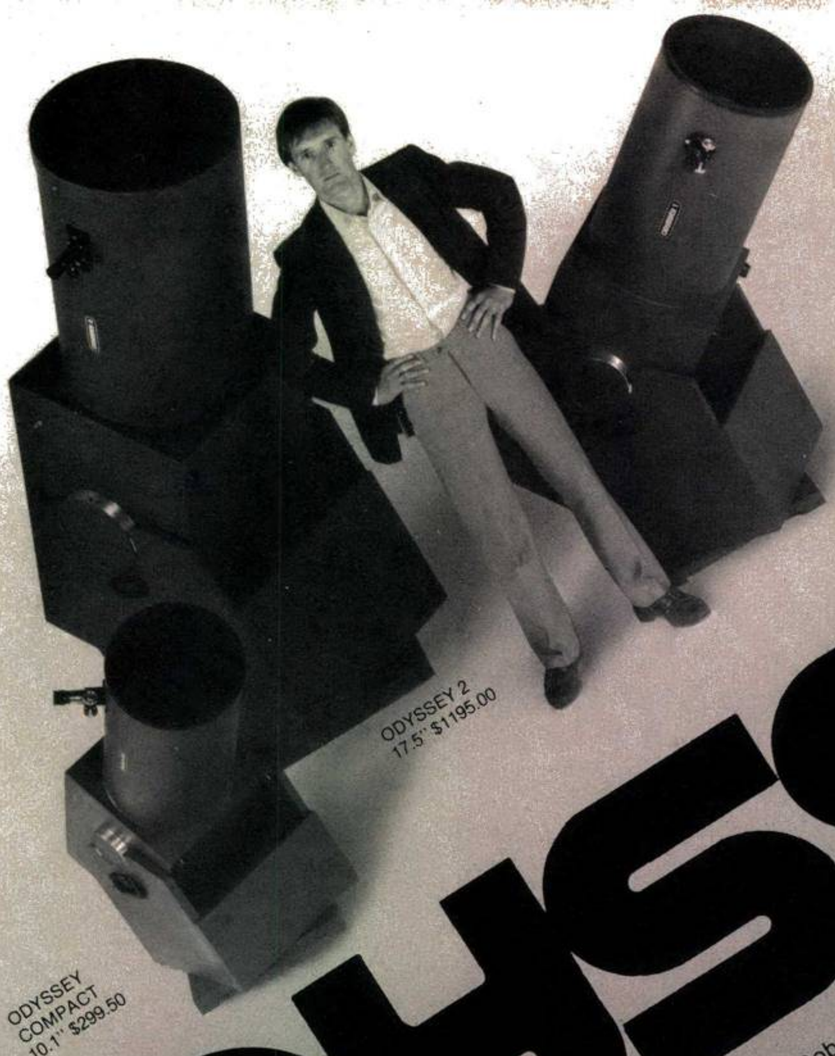

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alien skies

by robert freitas

If we stood on the surface of an alien planet, what would the sky look like? Might we see fluffy white clouds floating in a sea of blue, red sunsets and multicolored rainbows? Naturally we have no idea what native inhabitants (if any) could perceive — their sensory physiology may differ radically from our own. But if we permit ourselves the anthropocentric luxury of viewing their world through our eyes, what would we see?

Hundreds of millions of planets might rotate around stars within our Milky Way. We have no direct knowledge of these faraway lands, but it is likely that our own world is as exotic as any in the Galaxy. So perhaps we should begin by asking about Earth's skies. Almost immediately we come upon a mystery; most of the constituents of the atmosphere — five billion tons of nitrogen, oxygen, noble elements, carbon dioxide, water vapor, traces of dust and various aerosols — are quite colorless gases, yet our sky has a beautiful deep blue color. Why?

About a century ago two English scientists, John Tyndall and Lord Rayleigh, wondered about this and independently set out to find the answer. Tyndall, the experimentalist, discovered that light rays passing through any transparent gaseous medium are deflected randomly out of the beam — differently according to their color, and more as the distance traveled increases. These deflections are part of a process which Tyndall called scattering. Later, Rayleigh — the theoretician — calculated that for particles as small as molecules of air, the intensity of scattering should be proportional to the inverse fourth power of wavelength. In other words, if wavelength is doubled, sixteen times less light is scattered away. As Tyndall found, this produces an especially striking color selection effect. Blue light, which has a very short wavelength, is scattered, whereas red light, with a relatively long wavelength, is hardly scattered at all.

> *When light is scattered by particles which are very small compared to any of the wave lengths, the ratio of the amplitudes of the vibrations of the scattered and incident light varies inversely as the square of the wave length, & the intensity of the lights themselves at the inverse fourth power.*
>
> *Lord Rayleigh's law explaining why the sky is blue. From an 1870 manuscript.*

It is easy to apply this to sky color. Sunlight is a mixture of all wavelengths in the visible spectrum from red through orange and yellow to green and blue; they add up essentially to "white" light. As the Sun's rays penetrate the atmosphere, they are scattered by air molecules — a little red and some yellow but mostly blue. Against the black background of space, each cubic meter of the atmosphere contributes to the total scattered brightness, so predominantly blue light appears to come from every direction we look and gives us our blue sky.

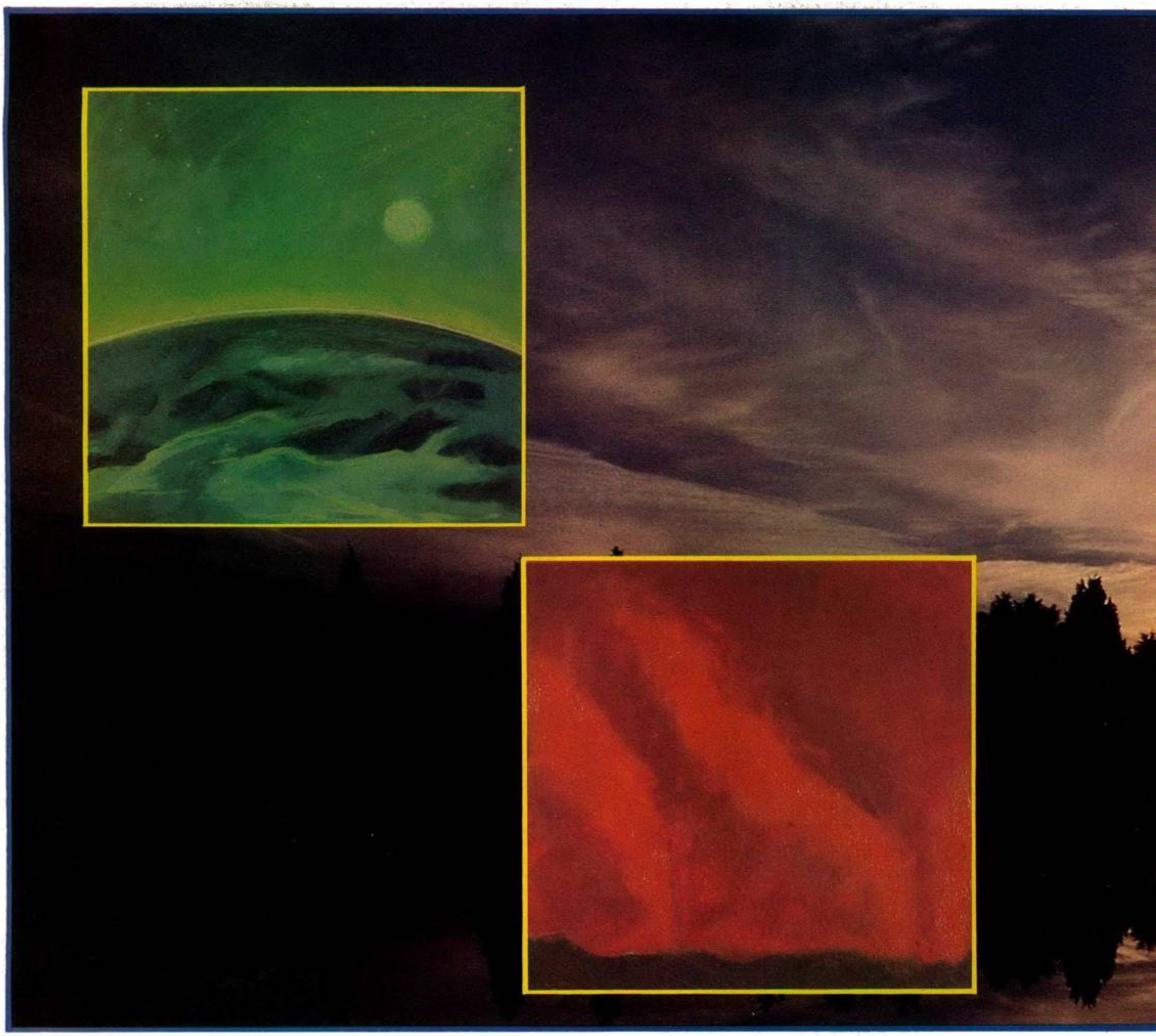
Lord Rayleigh's theory may be adjusted to account for differences in temperature and surface pressure that might be found on other worlds. The denser the air the greater the deflection of light, so from the simple physics of gases, we know that the intensity of scattered skylight must be proportional to pressure divided by temperature. More light is scattered by cold thick air, less by a warm and thin atmosphere.

Hence on Mars, where the air is a hundred times more rarefied than on Earth, sky brightness due to Rayleigh scattering should be only about one percent of its earthly intensity. If not for the red surface dust kicked up by winds, the martian daytime sky would remain starry black at zenith with a faint trace of violet near the horizon. Similarly, Rayleigh scattering in the hot, thick venusian atmosphere is about forty times the terrestrial amount. Under these extreme conditions all colors are strongly deflected leaving a dull, featureless white sky, a fact confirmed by Soviet and American space probes that have visited the planet's surface in recent years.

But Rayleigh theory has its limitations. It can only be used to describe scattering by particles much smaller than the wavelengths of radiation affected. In the case of visible light, for example, the theory doesn't work for particles bigger than about two-tenths of a micron (1 micron = 0.000001 meter). These larger sizes require a more complex mathematical treatment devised by Gustav Mie earlier in this century.

Mie theory occasionally gives simple results. For instance, it correctly predicts that particles bigger than four microns (less than a tenth the thickness of the paper on which these words are printed) scatter all wavelengths of light about equally. This explains why true visibility is usually far less than the theoretical maximum of 300 kilometers in pure dry air. Literally tons of large aerial dust motes, suspended salty ocean spray particles, bits of disintegrated micro-meteorites and water droplets larger than four microns float high above each square kilometer of our planet. Our atmosphere's deep natural blue is washed

Mars would lose much of the pale orange tint of its sky if not for the red dust that blows from its surface. Planetary scientists originally thought the planet had a blue sky similar to our own. NASA/JPL photo.



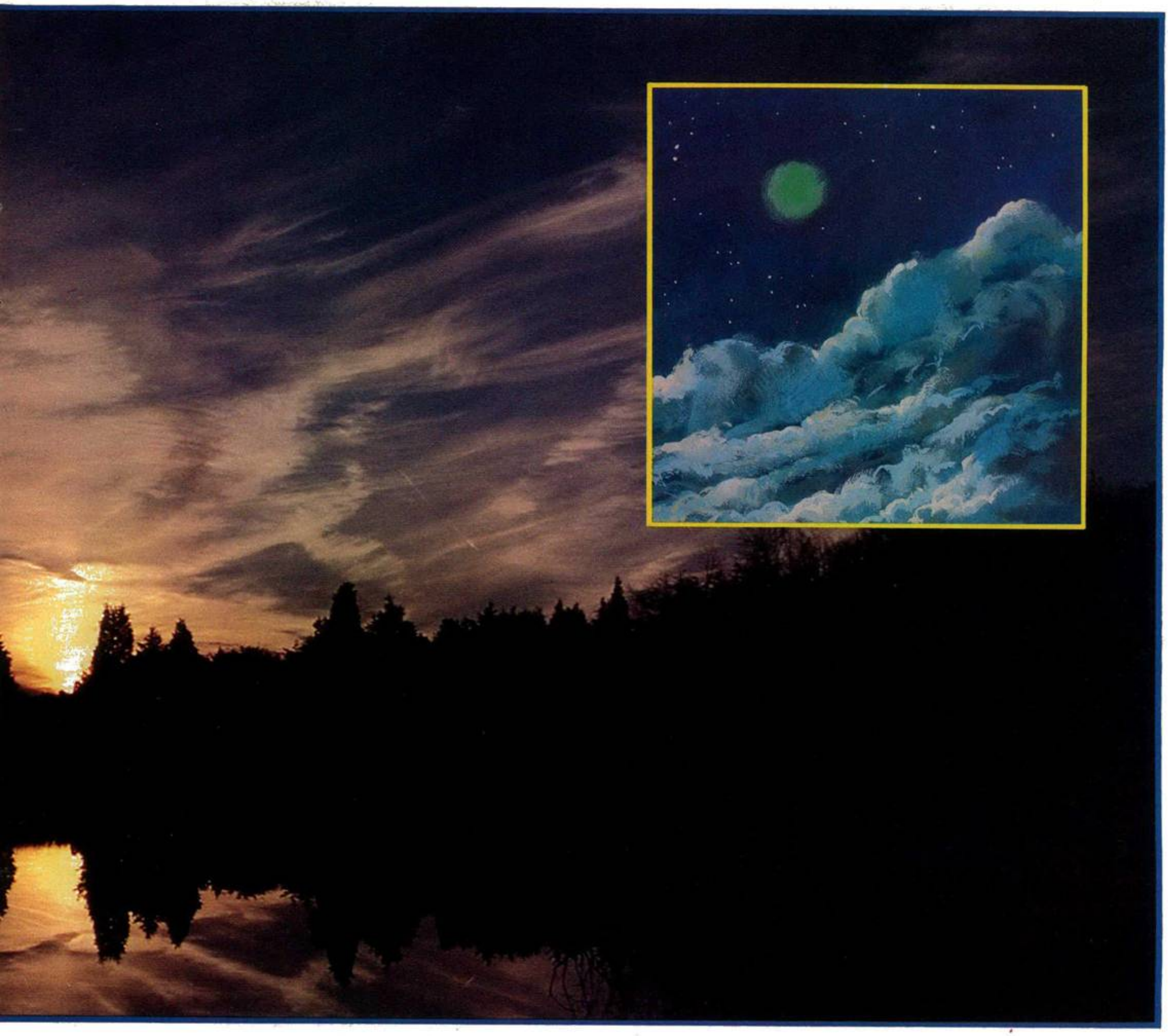
out with an obscuring white haze, leaving the familiar light blue hue of Earth's skies.

But Mie theory becomes somewhat complicated for particles 0.2 to 4 microns in size. Scattering is again selective according to the wavelength of light, but no longer follows the simple inverse-fourth-power rule discovered by Lord Rayleigh. Instead, the preferred color varies with increasing particle size. Motes of certain radii scatter blue best, but others deflect more red or green than any other color. This unusual effect — proven in the laboratory with artificial aerosols — is remarkably sensitive to particle size. For example, a uniform haze of 1.1 micron droplets scatters more blue and creates a blue sky, but similar clouds of 0.7 micron drops preferentially scatter red light and produce a red sky. Particles either 0.5 or 1.5 microns in radius deflect slightly more green light than blue or red, so an atmosphere loaded with these and illuminated by white light would assume a faint berylline or bluish-green hue.

Natural fogs and mists are random mixtures of droplets from one-hundredth of a micron to ten microns and larger so we normally don't see such vivid colors. Each size preferentially scatters a different wavelength, which averages out to the milky white or ordinary fogs and clouds. However, "blue fogs" have been sighted in very special circumstances. Natural processes could produce particles close to a single diameter, what specialists call a "monodispersion," and sow these throughout the atmosphere of some distant planet, perhaps producing colorful skies. Many scientists believe that in our own solar system the preferential scattering of blue and violet light in the volcanic plumes of Io may be caused by a one micron haze of sulfur particles suspended in the tenuous ionian atmosphere.

If the light scatterers themselves have color, the atmospheric colors will vary even more. A red particle, for instance, absorbs all light but red — which it reflects. Thus it appears reddish to our eyes. Yellow matter tends to absorb blue and red. In theory, an atmosphere heavily laden with dark yellow dust particles should take on a soft golden color as if touched by the hand of Midas.

Some of the first pictures returned by the Viking I lander from the surface of Mars showed a bright martian sky. At the outset, mission scientists naively believed it had to be blue, and several early photos were produced under this assumption. Much to the embarrassment of imaging team specialists, subsequent processing of colorimetric

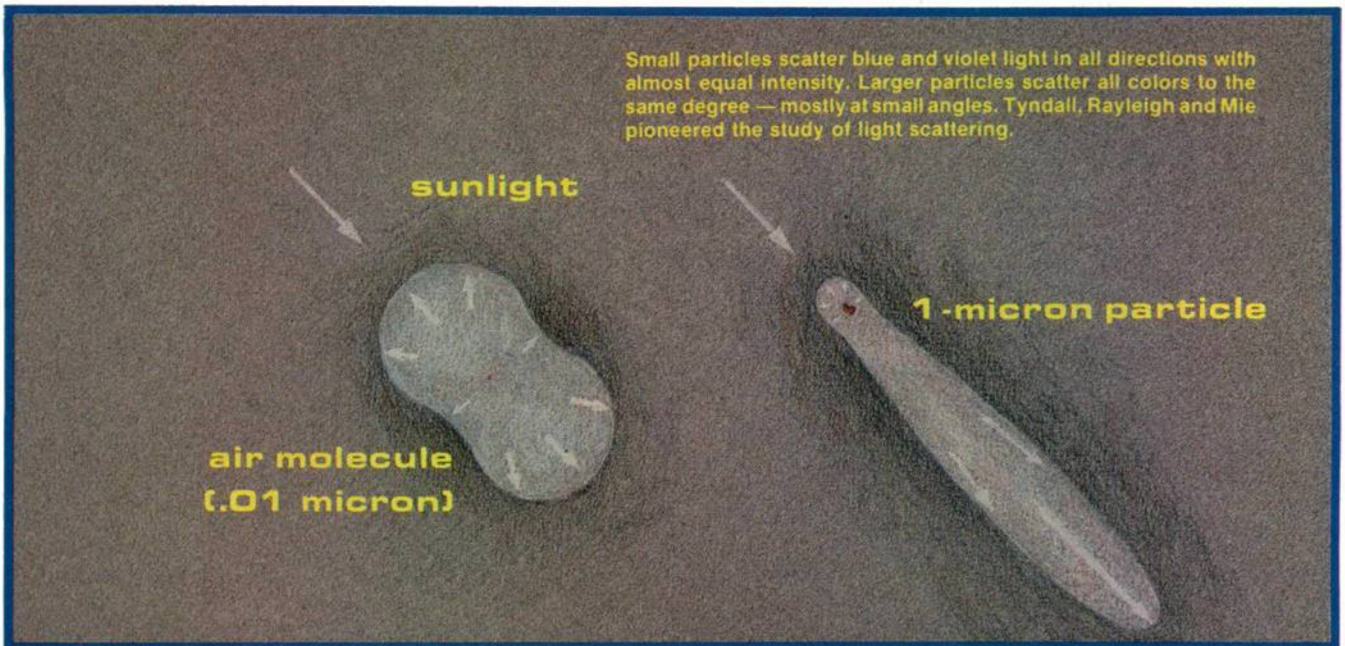


If you lived on a planet with a small amount of chlorine in its atmosphere, you'd wake to a sickly chartreuse sun rising in a sky of almost the same pale color (far left). Lightning in a neon-saturated atmosphere would discharge at a much lower voltage than that in earthly skies and might continuously bask a planet in the eerie glow of diffuse orange-red streamers (left). A green sun would dominate an intense blue sky over a planet with methane and ammonia in its atmosphere (above). In the background is the less exotic but still beautiful Earth atmosphere. Paintings by Barb Ericksen. Photo by Alan D. Helms.

data revealed that the true sky was orange-red. Mie scattering from relatively large particles produced a bright haze, and absorption by the dust itself gave the sky the orange cream color of the martian soil — but a hundred times more luminous than Rayleigh scattering alone could. We may imagine strange skies of almost any conceivable hue if we can find a planet with a fine enough surface dust of the proper color.

Alien air molecules also may absorb light selectively. Nitrogen and oxygen in Earth's atmosphere are extraordinarily transparent, but many other gases absorb specific colors. Methane and ammonia, common constituents of the gas giant planets, are weak absorbers of red light, so astronauts floating deep in the atmospheres of Uranus or Neptune might observe a lovely green sun against an intense blue sky. Ozone in Earth's stratosphere absorbs strongly in the ultraviolet (this protects us from fatal sunburn) and less strongly in yellow and orange light, so the gas is bluish. A world with a much thicker ozone layer would have a deep blue sky with just a hint of purple and a fierce blood-red sun. The reddish-brown color of photochemical smog over major cities is mainly due to the absorption of blue and green by molecules of nitrogen dioxide in the air. Colorful hydrocarbons and other organics in the atmosphere of Titan — Saturn's largest moon and the only satellite in the solar system thought to have an atmosphere — may produce vivid skies painted with gorgeous orange and red streaks and whorls.

On a more speculative note, what if our descendants someday land on a planet inhabited by chlorine breathers? This alien alternative to oxygen so beloved by generations of science fiction writers transmits green light while



Small particles scatter blue and violet light in all directions with almost equal intensity. Larger particles scatter all colors to the same degree — mostly at small angles. Tyndall, Rayleigh and Mie pioneered the study of light scattering.

Clear Sky Color of an Earthlike Planet Orbiting Various Star Types

Color Scattered	F0 (Blue-White Sun)	G0 (Yellow Sun)	K0 (Orange Sun)	M0 (Red Sun)	M5 (Redder Sun)	M8 (Reddest Sun)
Blue	71%	69%	60%	45%	32%	23%
Yellow	22%	23%	28%	34%	38%	38%
Red	7%	8%	12%	21%	30%	39%
Sky Color	Violet-Blue	Deep Blue	Powder Blue	Blue-tinged White	Yellow-tinged White	Orange-Yellow

absorbing blue and red. Chlorine gas present at a concentration of only a few hundred parts per million in an atmosphere similar to that of Earth would make a sickly pale chartreuse sky and sun.

On a pressure-cooker world like Venus, we must consider yet another factor: thermal blackbody radiation. A "black body" is an ideal in physics, a theoretical perfect absorber and emitter of radiation. Just as burners on an electric stove glow red when they are hot, so will an entire world at high enough temperatures. Dark-adapted human eyes can detect the visible blackbody radiance of any solid object heated above 700 K, so the 750 K venusian surface should glow with a dim red incandescence about as bright as the light from a crescent Moon. Since sky brightness at ground level on Venus is about the same as daylight on Earth under heavy overcast, astronauts outside during the long venusian day would see ordinary rocks. But at night, the plains and sky of our sister planet would show a dull orange glow.

All sky light derives from sunlight — and suns come in many colors. Might it be possible to skew the normal Rayleigh scattering spectrum by starting with much redder light from a cooler star? The table above gives the clear sky colors for a hypothetical Earth occupying the habitable zones of various suns. Blue of some shade normally predominates. However, an earthlike world circling an M5 star could have a white sky with a trace of yellow, and around the coolest, reddest M8 stars our planet's skies would take on a distinctive orange-yellow hue. Yellow sky can sometimes be seen on Earth near the reddened setting Sun, since our eyes are more sensitive to this color than the blue which is also strongly scattered out of the direct solar rays.

But what would the Sun look like? Under air that scatters blue (blue sky) or absorbs blue preferentially (yellow or red sky), starlight loses blueness and becomes redder. This is why our Sun appears more yellow from the ground than its true appearance when viewed from space. The effect is most striking at sunset when solar rays must traverse up to thirty kilometers of the dense lower atmosphere. Blue and green are completely attenuated, leaving only fiery red. On another world with much colder, denser air, Sol would look cherry red at high noon and dull crimson near sunset. Clear sky might remain powder blue, but passing clouds would wear scarlet stains from dawn to dusk, and surface objects such as trees, mountains and houses would appear redder and less colorful.

The opposite would occur beneath an atmosphere that absorbs red (blue sky) or scatters red preferentially (red sky). On such planets a sun will lose redness and become bluer. North America and Europe were treated to the sight of a violet-blue sun in late 1950 when raging fires covered a quarter-million acres of Canadian forestland. Observers have also spotted an occasional green Sun; and a "blue Moon" appeared after the great volcanic eruption at Krakatoa in 1883 dispersed fine red-scattering particles high into the atmosphere.

Standing on some strange alien world, we might also see a number of fascinating refraction phenomena. Refraction is the bending of light rays toward a denser medium — thicker air — in which photons travel more slowly. A mirage is one example which occurs when a layer of hot air accumulates close to the ground. This air, since it is hotter, is less dense. The layer acts as a giant lens. Light rays from above the horizon swoop down close to the ground, then bend back up toward the cooler thicker air above. The mirage of water on an asphalt road is simply a smeared-out image of blue sky. Usually these phantom lakes form about a hundred meters ahead of the observer. On Mars the atmosphere is so thin that surface air is hardly heated at all and the refraction layer must be less pronounced. If they exist at all, martian mirages should look like faint shimmering pools of liquid orange at least a kilometer away.

Starlight bends toward the surface as it enters the dense spherical atmosphere around a planet. This alters the visual appearance of celestial objects. For instance, as dusk approaches, sunlight must travel farther through thicker air, hence the Sun looks a tiny bit higher in the sky than its true position. Also, rays from the upper limb penetrate thinner air than those from the lower limb, so top and bottom appear to converge slightly. This effect is barely noticeable during sunsets on Earth, but viewed through a far more dense atmosphere the image of the setting Sun could be squashed by a factor of ten or more, reducing it to a thin sliver of light.

Refracted light is sorted by color, a process called dispersion. Shorter wavelengths are bent more than long wavelengths — red just a little, blue the most. The flattened images of the Sun or the Moon are pulled out into a vertical spectral smear with red at the bottom and green at the top — blue light is Rayleigh scattered. On Earth this effect distorts pointlike stellar images and manifests itself in the colorful "starbows" and "planetbows" that plague the users of small telescopes observing the planet Venus when it's low in the sky. In much thicker atmospheres, the dispersion could easily be visible to the naked eye, giving a soft "sunbow" or "moonbow" up to ten arc-minutes in vertical size. For comparison, the Sun and Moon are about thirty arc-minutes wide as seen from Earth.

The "green flash" is a related refraction phenomenon. In very clear skies, particularly over the ocean, you'll sometimes see a brilliant emerald flash just as the uppermost edge of the setting Sun dips below the horizon. The explanation is fairly simple. At the moment of flash, red and yellow light are not bent enough to reach the observer from below the horizon. Only the green and blue components of the Sun's rays are sufficiently refracted to navigate the curve of the Earth. But the blue is preferentially removed by Rayleigh scattering. This leaves only the green, which appears as a vivid emerald flicker as the Sun sets.

Solar and lunar flashes could be quite spectacular on other worlds. Blue or violet flashes may be the rule on planets with very thin air and not much particulate matter suspended in their atmospheres. Some observers report blue flashes at the instant of sunset, but only at very high altitudes. On a high-pressure world where both green and blue are strongly scattered, yellow flashes may occur. And if a day on this hypothetical planet lasts as long as one on Venus, the ephemeral flash could become a radiant glow to be savored for more than a minute.

Perhaps the most familiar refraction effect is the rainbow. This beautiful spectral arc is caused by airborne liquid droplets which act as tiny individual prisms to separate incoming light into its constituent colors. The chromatic bands are partial segments of concentric circles centered on an imaginary line drawn from the observer to the light source. The lower the source in the sky, the more of each color band is visible. So winter bows are larger than summer bows, and planets with highly tilted axes — such as Uranus — will experience greater seasonal variation in size and luminosity of rainbows than worlds with smaller tilts.

Depending on the characteristics of the alien atmosphere and the sources of light, rainbow colors may vary. A hot blue-white star will produce vibrant colorful bows, while arcs under red suns may lack blue and green and would appear as faint orange and red bands. A red-absorbing atmosphere may permit rainbow arches only of green and blue. If bright moons or multiple suns hover nearby, several bows could appear in the sky simultaneously — each one of a different size and color, and oriented in a different direction.

Big droplets make brighter bows, since they refract more light. But what determines the maximum size of raindrops? Gravity is one important factor. On heavy worlds, liquid particles may fall from the sky before they can grow very large. On less massive planets rain can fall more slowly, so droplets should grow larger. Surface tension — the force that pulls a blob of liquid into a perfect sphere as it falls through the atmosphere — also plays a role. The surface tensions for most transparent liquids of astronomical interest are significantly lower than that of water and, with the possible exception of liquid hydrazine, should form smaller droplets and much less impressive rainbows. In addition, drops may grow larger in cold thin air. Chances are that the most dazzling rainbows in the Galaxy will be found on chilly, low-gravity water worlds with tenuous atmospheres.

Another awesome atmospheric phenomenon is lightning. It usually strikes during electrical storms, in the shape of bolts, sheets, beads, balls, and other exotic forms. Electrical storms occur when air molecules are split into charged ions in the upper atmosphere and carried to the ground by the fall of dust particles and rain. The planet charges up like a giant condenser, with a potential of millions of volts from ground to cloudtops, and eventually discharges with a blinding stroke accompanied by deafening peals of thunder.

Where might we find the most violent discharges? The single most important factor is the breakdown voltage of the air — the electrical potential required to induce a spark to jump a gap of unit distance. The gap voltage for pure and dry sea-level air is about a million volts per meter, though a much lower dose than this can still initiate atmospheric discharge in stormy humid air saturated with ionized particles.

Gases such as chlorine and fluorine have gap voltages as high as earthly air, but many others, including hydrogen and the noble gases, are considerably more conductive. Because neon has a gap potential as low as only 80,000 volts per meter, planets with large amounts of this gas will have more frequent but less severe lightning activity. In fact, neon lightning might be large diffuse streamers of orange-red luminescence, and neon thunder would probably hiss rather than rumble. Gap voltages for gases tend to increase when temperatures of worlds with hot, thin atmospheres will be treated to fewer but far more violent lightning displays.

And aurorae? These delicate wisps of yellow-green and red appear most regularly in an annular region ten or fifteen degrees from the north and south magnetic poles. They are caused by the funneling of charged solar wind particles in the converging planetary magnetic field lines. Hotter stars should have more vigorous solar winds to provide charged ions, and fast-spinning massive worlds stronger magnetic fields to contain them. This combination could produce glow discharges of far greater intensity than any seen on Earth. The best place in the Galaxy for aurora-watchers might be a four-earth-mass planet — with a well-magnetized nickel-iron core and a ten hour day — circling a hot F5 star.

We have sent our imaginations across the cosmos to speculate on nature's handiwork. But the cold verse of scientific prose probably cannot begin to convey the alien beauty of chromatic clouds and rainbows and aerial vistas of every conceivable hue and tincture. Yet if we look to the future — beyond Voyager, beyond Galileo, and beyond even our own solar system to the millions of planetary systems that could populate our Galaxy — we may someday be fortunate enough to see with human eyes the striking sunrises and sunsets, and variegated atmospheres of Alien Skies.

Robert Freitas has degrees in physics, psychology and law. He has published his work in various science and science fiction magazines.

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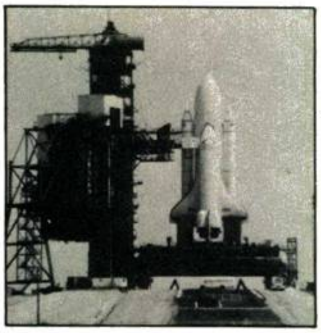

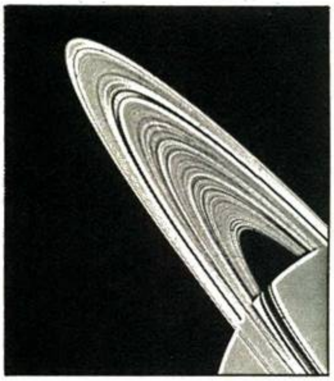

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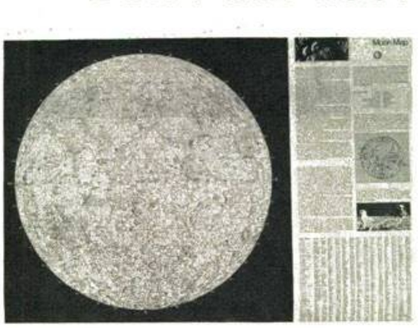

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WANTED — Correspondence with persons (all ages — I'm I7) interested in astronomy, making simple telescopes, programming with HP-41C, or anything. Contact Bambang Suemarwoto, Jl. Cimandiri 16, Bandung, Indonesia.

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WANTED — Pictures, preferably color, of the aurora borealis or aurora australis. Contact David Epstein, 4927 Gloria Ave., Encino, CA 91436. Phone (213) 986-1697.

WANTED — Contact with astronomers interested in astrotheology and/or the "cosmic religious experience," which Einstein said was the source of his creativity as a theoretical physicist. Contact Arthur J. Schoellkopf, P.O. Box 424, Green Springs, OH 44836.

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WANTED — Correspondence with persons 13 and up (hopefully females) interested in astronomy, TSR role-playing games, SF movies and science. Contact Nathan Reed, 345 N. Collier, Coquille, OR 97423.

WANTED — Correspondence with persons age 12 to 15 interested in astronomy and collecting stamps. Contact Geoff Haynes, 14312 Ravine Drive, Edmonton, Alberta, T5N-3M3, CANADA.

WANTED — Correspondence with persons (ages 16-21) interested in astronomy, reading, music, NASA, traveling and sharing their faith. Contact Lissa Hilld, 20339 Temple Ave., Walnut, CA 91789.

WANTED — Correspondence with male pen pal by 29 year old Philippino girl. Contact Ursula Vergara, Int. 7-C-F Nazario Ct., Barrio Tijeros, Makati, Metro Manila, PHILIPPINE ISLANDS.

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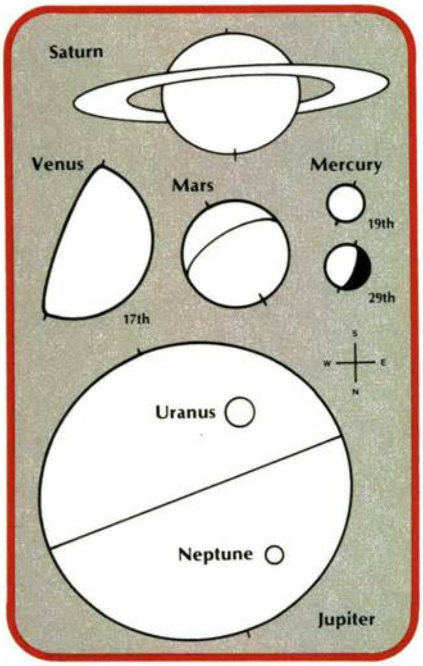
Mercury

Mercury will be lost in the Sun's glare for most of April. By about the 20th, however, it will reappear low in the west-northwest after sunset. Between then and the end of April, it rises swiftly to about 10° elevation 45 minutes after sundown. Greatest elongation comes on May 9 — greatest elevation about a day or two earlier. The evening apparitions this month and next will be the year's best, so you won't want to miss them.



Venus

At greatest western elongation on the 1st, Venus is slightly lower in the predawn eastern sky compared to its position in the past two months. Its brilliance is fading, though it remains a very conspicuous sight. Our sister planet's disk now looks like a tiny and featureless Last Quarter Moon. Over the months to come, you'll see it grow smaller and rounder in your eyepiece.

Mars

Though it reached opposition on the last day of March, Mars won't be at its closest to Earth until May 5, because the orbits of Earth and Mars are not precisely concentric. But for practical purposes, the difference in distance is negligible: 438,000 kilometers.

If you observe Mars at the exact same time every night, the 40-minute difference between the terrestrial day and the longer martian day will make Mars appear to rotate backward. Over the course of several weeks, you'll be treated to a night-by-night "tour" of martian geography. Take a map of Mars like the one published in the January 1980 ASTRONOMY and you'll soon be familiar with such famous martian sights as Mare Acidalium, Syrtis Major, and Lacus Solis.

Asteroids

1 Ceres (magnitude 7.1) is in central Libra, a little to the east of 2nd magnitude Beta (β) Librae. Its positions:

9th: 15h 39m 55s, -9° 31.6′
19th: 15h 34m 14s, -9° 19.7′

Ceres rises around 9 p.m. local time on the 15th.

2 Pallas (7.7) is at opposition on April 1. Moving retrograde, it lies to the southwest of Arcturus near Coma Berenices' border with Virgo. Its positions:

9th: 13h 09m 47s, +16° 52.7′
19th: 13h 02m 35s, +19° 23.2′

Pallas rises around sunset in mid-April.

3 Juno (10.9) lies in Scutum, mingling its light with that of the Milky Way. Its positions:

Lightning from a thunderstorm over the Pacific Ocean illuminates the horizon while the stars in the head of Scorpius arc above and move toward the west. Alfred Lilge took this photo from Huntington Beach, California, using a 2-minute exposure on Ektachrome 400 (2¼ square) with a 120 mm lens at f/2.8.

Left: On January 9, 1982, John Nassr photographed a total lunar eclipse from Baguio, Philippine Islands. He used an 8-inch f/10 scope, Fujichrome 100, and a 10-second exposure to win this month's "Best Astro-Photo" award. Right: Jean-Guy Moreau photographed NGC-7023 with 12-inch f/6 scope and a 15-minute exposure on 103a-F.

9th: 18h 32m 15s, -8° 45.2′
19th: 18h 35m 29s, -7° 59.1′

Juno rises around 1 a.m. local time on the 15th of the month.

4 Vesta (7.5) is in western Capricornus. Its positions:

9th: 20h 29m 48s, -18° 26.5′
19th: 20h 46m 12s, -17° 48.8′

Vesta rises at about 2 a.m. local time on the 15th.

(All asteroid positions are in 1950 coordinates.)

Jupiter

Both Saturn and Jupiter come to opposition this month; Jupiter is the easterly of the two, so it reaches opposition later than Saturn — on the 26th compared to the 9th. Unless you're an early riser, you'll probably find the "post-opposition hours" — the evening — a better time to observe.

Many neophyte observers find the pale and weak jovian features difficult to discern. They can find the two equatorial belts, but the Great Red Spot — found after several days of searching — appears neither great nor red. And for the life of them, they can't see all those wisps and festoons others have noted and discussed. What's wrong?

Nothing, really. Jovian details *are* faint — and only continued observations at the eyepiece will reveal them. But there's one thing you can do to give yourself an assist — use a colored filter. By blocking certain colors and transmitting others, a filter can bring out faint details that otherwise are lost.

Saturn

At opposition on the 9th, Saturn will be 8.67 AU (1.29 billion km) away.

As with Jupiter, Saturn's belts and zones are decidedly pastel and, in the case of Saturn, they are even less prominent. Filters will make only a moderate difference in what you can see — a blue one, for example, will darken the bands relative to the disk.

Look for color differences from one side of the rings to the other. Carefully observe the east and west extensions, or *ansae*, through filters and see if one side is brighter than the other. A full set of filters — violet, blue, green, yellow, orange, red — will work best, but even a red or a blue may unlock something. One caution: to avoid color-refraction effects in the Earth's atmosphere, observe when the planet lies close to the meridian.

Uranus

Back in January, Uranus passed eastbound between the two stars that together make up Omega (ω) Scorpii. It then slowed its direct motion, reversed, and will now pass back through the pair. Uranus will be 6′48″ of arc north of Omega[2] at 8:36 UT on the 30th; it then passes 3′37″ south of Omega[1] at 3:27 UT on May 4.

The best way to observe is to use a low-power eyepiece to locate the stars and then a medium-power to enlarge them. Uranus' 3.8 arc-second disk will shine at magnitude 5.8.

Neptune

Neptune is in eastern Sagittarius, about a degree south and 5 minutes of right ascension east of the 4.9 magnitude star 58 Ophiuchi. It was stationary in R.A. on March 29, and now retrogrades until September 6. The planet will be at opposition on June 17.

The Moon will occult the planet on the 14th, but the event isn't visible from North America.

Pluto

At opposition on April 15, Pluto will be long way from Earth — 4.3 billion kilometers — but not quite as far as Neptune (4.4 billion km). Our "most distant planet" moved inside Neptune's orbit in 1979, and will remain there until 1999.

Meteors

April's best — though not very active — meteor event is the annual Lyrid shower which peaks at 15h UT on the 22nd. Appearing to come from a region to the southwest of Vega, near the Lyra Hercules border, the Lyrids are moderately swift (50 km/sec), bright, and likely to leave trails. Unfortunately, they're also sparse. Depending on your local light-pollution levels, you may see up to 20 per hour — but expect about 5 to 10.

close-up on coma berenices

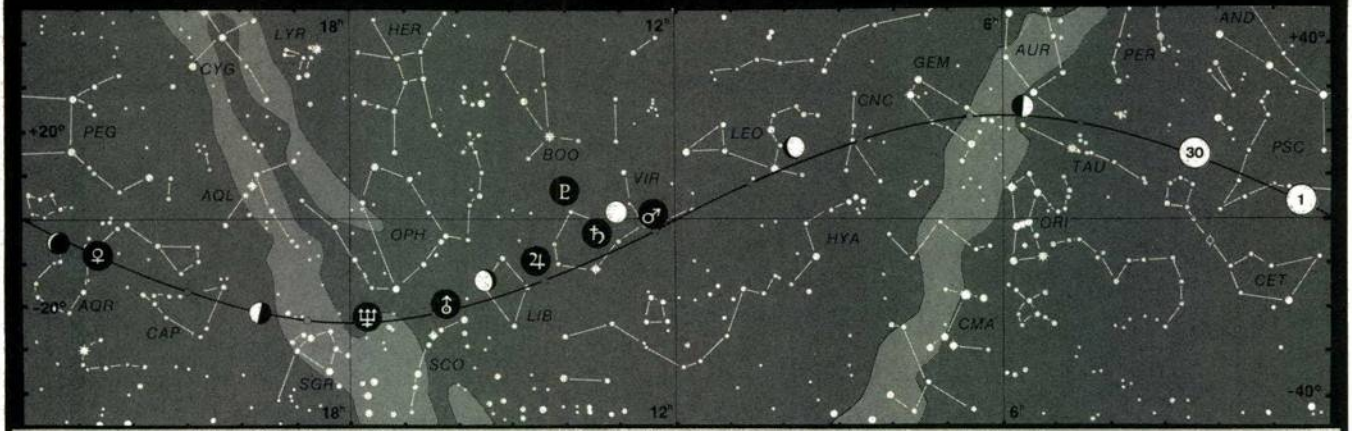
"Realm of Galaxies." That phrase has always conjured up exotic deep-space imagery, but it seems so distant, so unreachable. The fact is, a realm of galaxies floats high overhead during April evenings, and beckons observers to Berenice's heavenly tresses.

Long before modern astronomers knew the true nature of this section of sky, the ancients imparted a great deal of significance to the constellation **Coma Berenices**. For even though the "realm" is below the threshold of sight, the famous asterism of a widely-spaced open cluster lured observers to gaze and wonder about Berenice's Hair.

This area of sky may look unpromising to the naked eye but don't let that fool you — there are more than 3000 plotted extragalactic systems here. On dark, transparent nights, scores of these objects lie within the reach of a 6-inch scope. In fact, it's hard to sweep and not have one pop into the field.

So many "nebulae" are in this region that classical observers like

planetary data april 1982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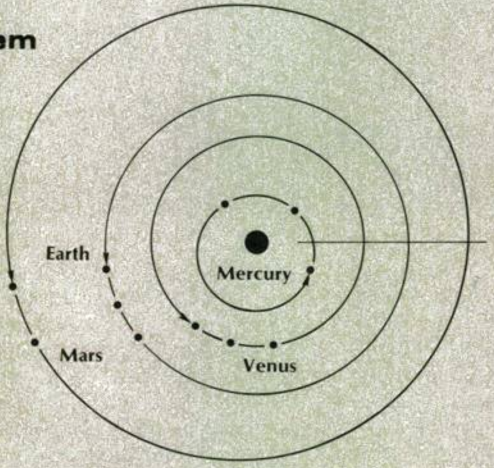
inner solar system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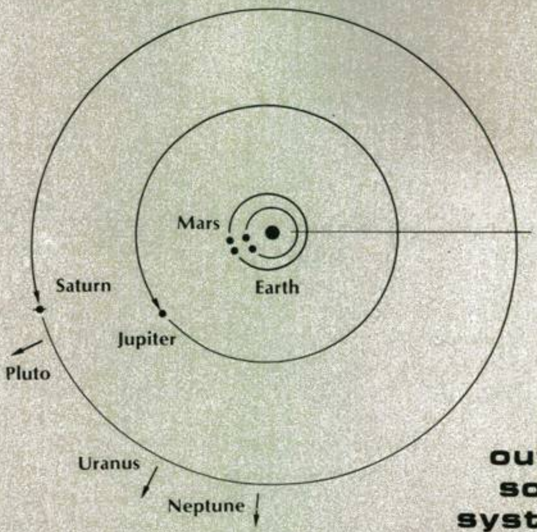

Mars
Earth
Saturn
Jupiter
Pluto
Uranus
Neptune

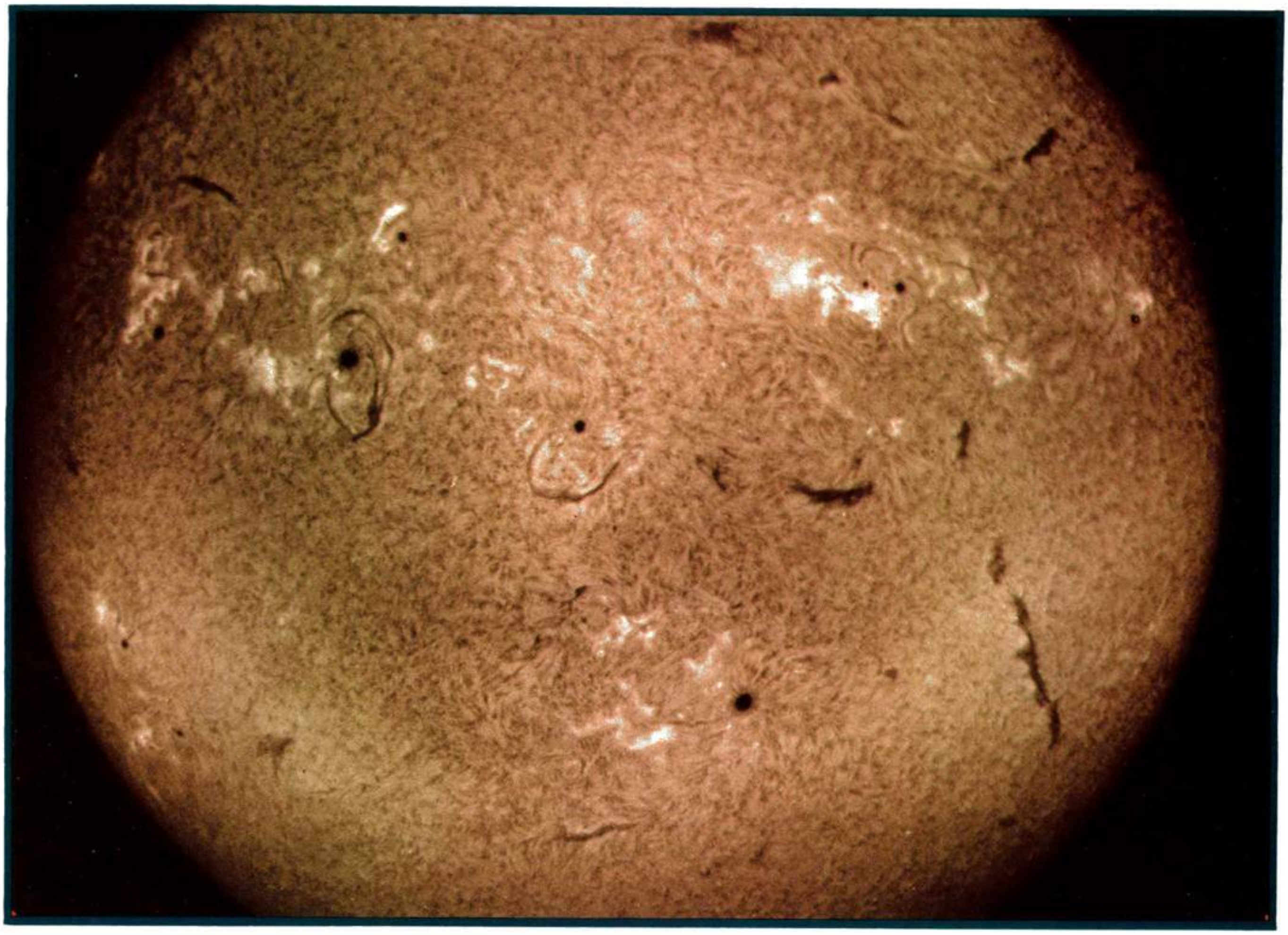
		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Sun	Longitude: Heliocentric	Ecliptic	R.A. (1982.3)	Dec
Sun		1	-26.7	32.1′	—	1.00	—	—	10°56.9′	0h 40.2m	+ 4°19.7′
		15	-26.7	31.9′	—	1.00	—	—	24°42.5′	1h 31.5m	+ 9°34.1′
		30	-26.7	31.8′	—	1.01	—	—	39°20.4′	2h 27.7m	+14°36.2′
Mercury	☿	1	-0.8	5.0″	94%	1.33	0.39	331°48.6′	359°48.0′	0h 04.1m	-1°45.2′
		15	-1.7	5.1″	99%	1.31	0.32	39°55.1′	27°55.3′	1h 45.7m	+10°39.3′
		30	-0.4	6.4″	64%	1.05	0.33	131°17.1′	57°00.1′	3h 39.0m	+21°44.8′
Venus	♀	10	-3.9	22.5″	54%	0.75	0.73	247°50.7′	333°08.7′	22h 21.2m	-9°44.2′
		30	-3.7	18.6″	63%	0.90	0.73	279°32.9′	354°33.7′	23h 43.3m	-2°58.4′
Mars	♂	15	-1.0	14.5″	99%	0.64	1.63	197°01.2′	184°38.9′	12h 22.3m	+0°18.7′
Jupiter	♃	15	-2.0	44.2″	100%	4.52	5.44	214°37.4′	216°23.1′	14h 20.0m	-12°25.7′
Saturn	♄	15	+0.5	19.2″	100%	8.67	9.67	199°06.7′	198°01.0′	13h 12.3m	-4°40.8′
Uranus	♅	15	+5.8	3.8″	100%	18.09	18.87	242°08.8′	243°33.3′	16h 08.5m	-20°48.1′
Neptune	♆	15	+7.7	2.5″	100%	29.79	30.27	265°17.7′	266°28.3′	17h 46.9m	-22°06.3′
Pluto	♇	15	+13.7	—	100%	29.01	29.97	205°32.8′	205°06.8′	14h 00.4m	+6°34.2′

moon data

First Quarter	April 1 at 5:08
Full Moon	April 8 at 10:18
Last Quarter	April 16 at 12:42
New Moon	April 23 at 20:29
First Quarter	April 30 at 12:07
Full Moon	May 8 at 00:45
Apogee: April 14 at 0h	404,668 km
Perigee: April 25 at 21h	362,586 km

universal time

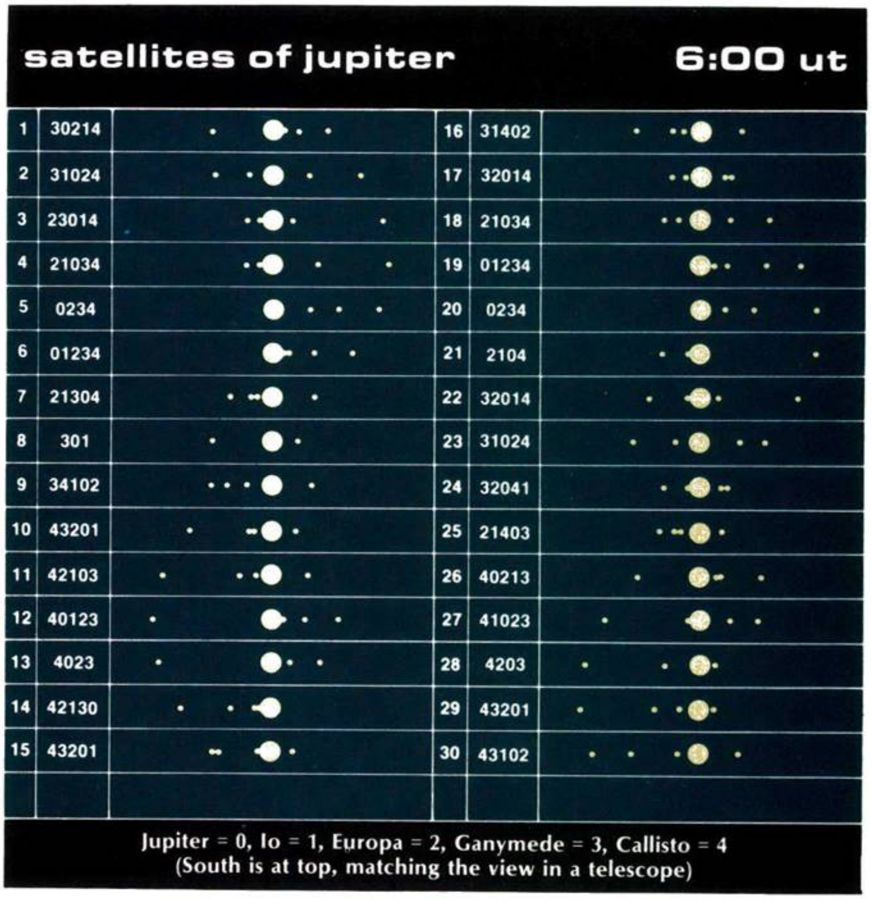
Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on January 2, then EST for the event is 10 p.m., January 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m., March 4.



The Sun's photosphere reveals complex features when viewed in the ruddy light of hydrogen-α. The bright features are regions of strong magnetic activity, the long dark streaks are feathery prominences projected against the photosphere, and the dark dots are sunspot umbrae. Photo by Edwin Hirsch.

Olcott, Webb, and Pickering avoided observing in Coma Berenices because of the difficulty in listing all of them. Webb summarized his observations by saying, "An especially remarkable constellation for those possessed of adequate optical means, on account of the wonderful nebulous regions, in which a far greater number of these extraordinary bodies are accumulated than in any other equal area of the heavens. Herschel detected more than 323. Few of them, however, are individually interesting: It is the mysterious thronging together of these objects, whatever may be their nature, that opens up such a field of curiosity. They are in general so much alike that I have only adduced a few specimens." Olcott agreed, "It is not possible to do more than glimpse the nebulae that this constellation features."

Actually, the similarity referred to by these observers was probably a result



satellites of jupiter **6:00 ut**

1	30214	16	31402
2	31024	17	32014
3	23014	18	21034
4	21034	19	01234
5	0234	20	0234
6	01234	21	2104
7	21304	22	32014
8	301	23	31024
9	34102	24	32041
10	43201	25	21403
11	42103	26	40213
12	40123	27	41023
13	4023	28	4203
14	42130	29	43201
15	43201	30	43102

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)

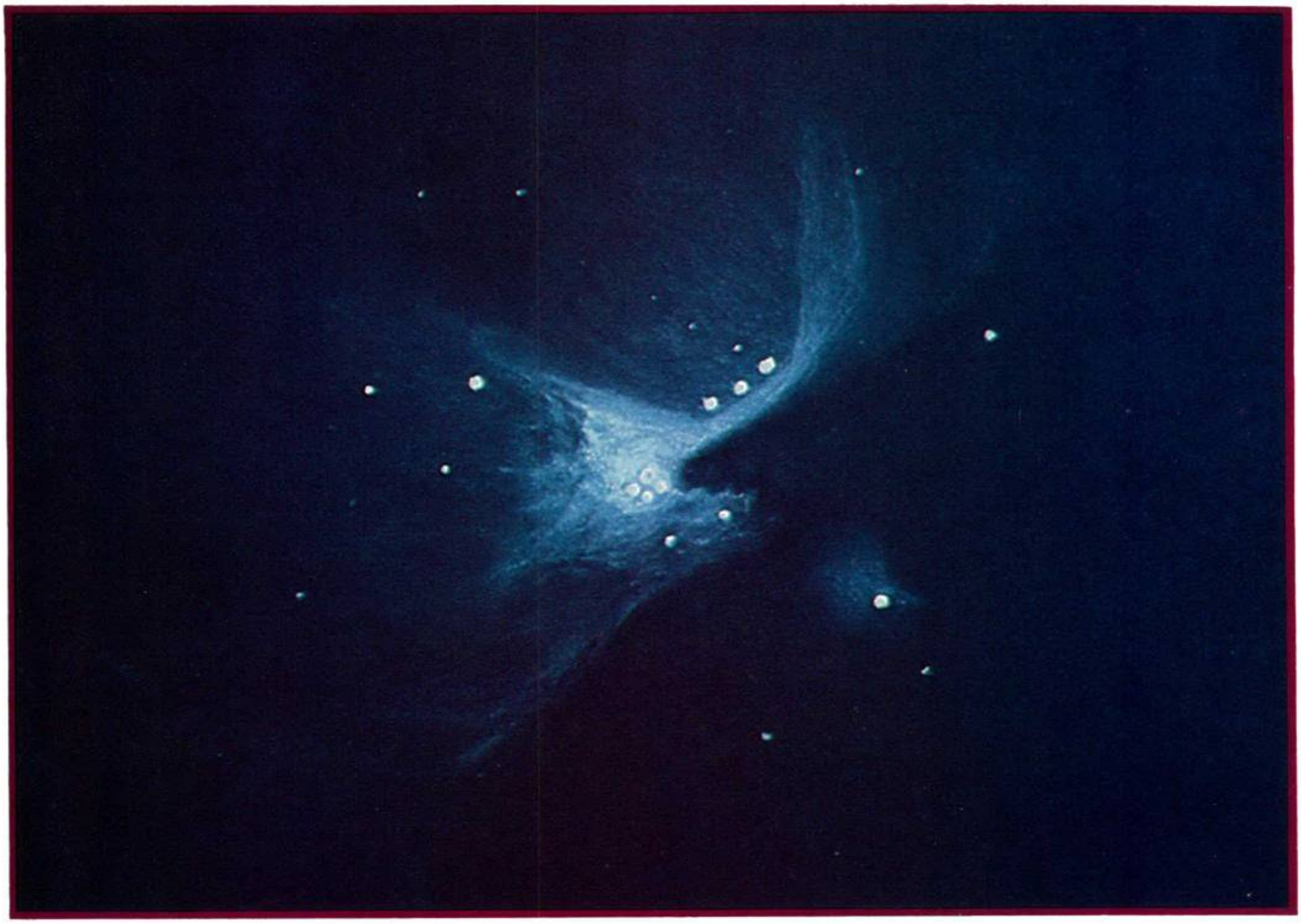
Above: Don Parker photographed Jupiter and Saturn near the time of their oppositions in spring 1981. The dot on Jupiter near its right limb is the shadow of Io. Right: Emery Hildebrand's photo elegantly captures the Moon two days after First Quarter, and provides a view of what the Moon looks like at about 20x.

of their small and unsophisticated telescopes. With today's good optics and medium-sized apertures, backyard astronomers can detect very different features for each galaxy in the region. Of course, some objects will still lie outside your telescope's light grasp, but in those that don't, you can detect a surprising number of shapes: pinwheels, needle-spikes, arcs, and ellipticals as well as light and dark areas within certain members. We are much luckier today. Serious *observers can do astronomy a favor* by giving detailed eyepiece impressions of many of these island universes in the realm of galaxies. Before you begin a night of observing in this constellation, pause and consider the words of Copeland. "Why should we bother to look at these galaxies, which are often hardly discernible in amateur telescopes? Not for what they seem to be, but for what they are: Each is a distant Milky Way seen by light millions of years older than prehistoric man. They can help us gain true *perspective — we and our world are* the minutiae and curiosa — galaxies are the grand realities. Thoughts like these explain why some of us pass leisure hours hunting for tiny, misty spots. . . For us, those hazy blobs and splinters of light are among the major details of existence."

Before bending to the eyepiece, note the rather large asterism the constellation is famous for. The **Coma Berenices Star Cluster** is one of the best known naked eye asterisms, rivaling the Pleiades and Hyades. Covering an area of nearly 5 degrees, the cluster is best seen with the eye alone or with wide-field binoculars; it loses its charm in the telescope. The cluster's center is a group of fifth magnitude stars, and many fainter stars hover on the threshold of sight. It is centered betweeen Alpha Canum Venaticorum and Beta Leonis, but any observers who look up in this direction during April will be sure to notice the filmy effect of barely distinguishable stars. This cluster's rising heralds the advent of spring for the northern hemisphere.

Next we come to an unusual pair of objects — the closely-spaced globulars, **M-53** and **NGC-5053**, separated by only one degree. M-53 lies one degree northeast of **Alpha Comae**, is easy to locate, and appears rich in even small scopes. Messier discovered it in February 1777 and found it condensed, but lacking in stars. In a 3-inch scope it appears as a round, nebulous spot, but resolves easily with larger apertures. Webb hailed it as "a brilliant mass of minute stars, blazing in the center." It is listed as eighth magnitude and lies at a distance of 65,000 light-years. M-53 is certainly one of the best globulars in the heavens, whetting our appetite for a summer filled with globular cluster observing. One degree to the southeast is the cluster NGC-5053, which still confuses observers. It is not quite dense enough to be a typical globular, but is far too packed to be classified an open cluster. Whatever its nature, it is interesting to see two such objects in close proximity. NGC-5053 shines about 10th magnitude, is easy to find, and forms a flattened triangle with M-53 and the wide double star **Diadem**. Begin the night observing in the area around Alpha and you won't be disappointed.

Start your galactic tour with **M-85**, a 10th-magnitude elliptical galaxy similar to many in this constellation. Webb called it "a fair specimen of the many objects in this region." Messier called it "a nebula without a star, above and near to the ear of Virgo, it is



When friends said that "the real thing" wasn't as impressive as photographs, Janis Romer decided to make sketches of the objects she observed. Using black pastel paper, chalk, a sponge to wipe-in nebulosity, and an eraser and black pencil to fix mistakes, she made this fine drawing of the Orion Nebula.

very faint." It measures 3 x 2 minutes of arc, and astronomers discovered a supernova within it in 1960. Lying in the same field but 8 minutes to the east is the faint barred spiral **NGC-4394**.

Next we come to the **Black-Eye Galaxy, M-64**, discovered in 1779 by J.E. Bode. It is an 8th-magnitude oval spiral 7 x 3 minutes in size. Visible in a good pair of field glasses, the Black-Eye becomes detailed in large scopes. It is rated as among the dozen brightest spirals in the heavens in the *Shapley-Ames Catalogue*. The structure of this galaxy is very unusual due to the massive dust cloud in the region of the central nucleus. With large scopes, you can break down the dust cloud into a great deal of fine detail; long-exposure observatory photographs show it to be an intricate area. The black-eye effect can be glimpsed in scopes as small as 6 inches in aperture, but you'll have to observe on a dark, clear night. M-64 is one of the most massive and luminous of all galaxies making it a noteworthy object for owners of smaller scopes.

Located ½° west of 5th-magnitude **6 Comae** lies the large, elongated spiral, **M-98**. Another "nebula without a star," this galaxy is about 10.7 magnitude and is nearly an edge-on spiral. M-98 is one of the few galaxies studied that does not exhibit a red shift! In fact, if our theories are correct, it is blue-shifted and approaches us at 125 miles per second! It could be a member of the Local Group, but its computed distance is nearly 35 million light-years — well outside the range of these relatively nearby galaxies. This galaxy is steeped in cosmological controversy.

A little more than 1.3 degrees to the ESE lies the bright, round spiral **M-99**. It is nearly circular, some 4 minutes in size, and about magnitude 10. M-99's spiral pattern is easy to detect and its arms are clumped with bright "star clouds and nebulous regions." You might even see the thin dust lanes in its nucleus. Lord Rosse called it a wonderful object and noted three arms although the existence of the third is still disputed. Take a look at this remarkable spiral even if you have a small scope — you're bound to see something.

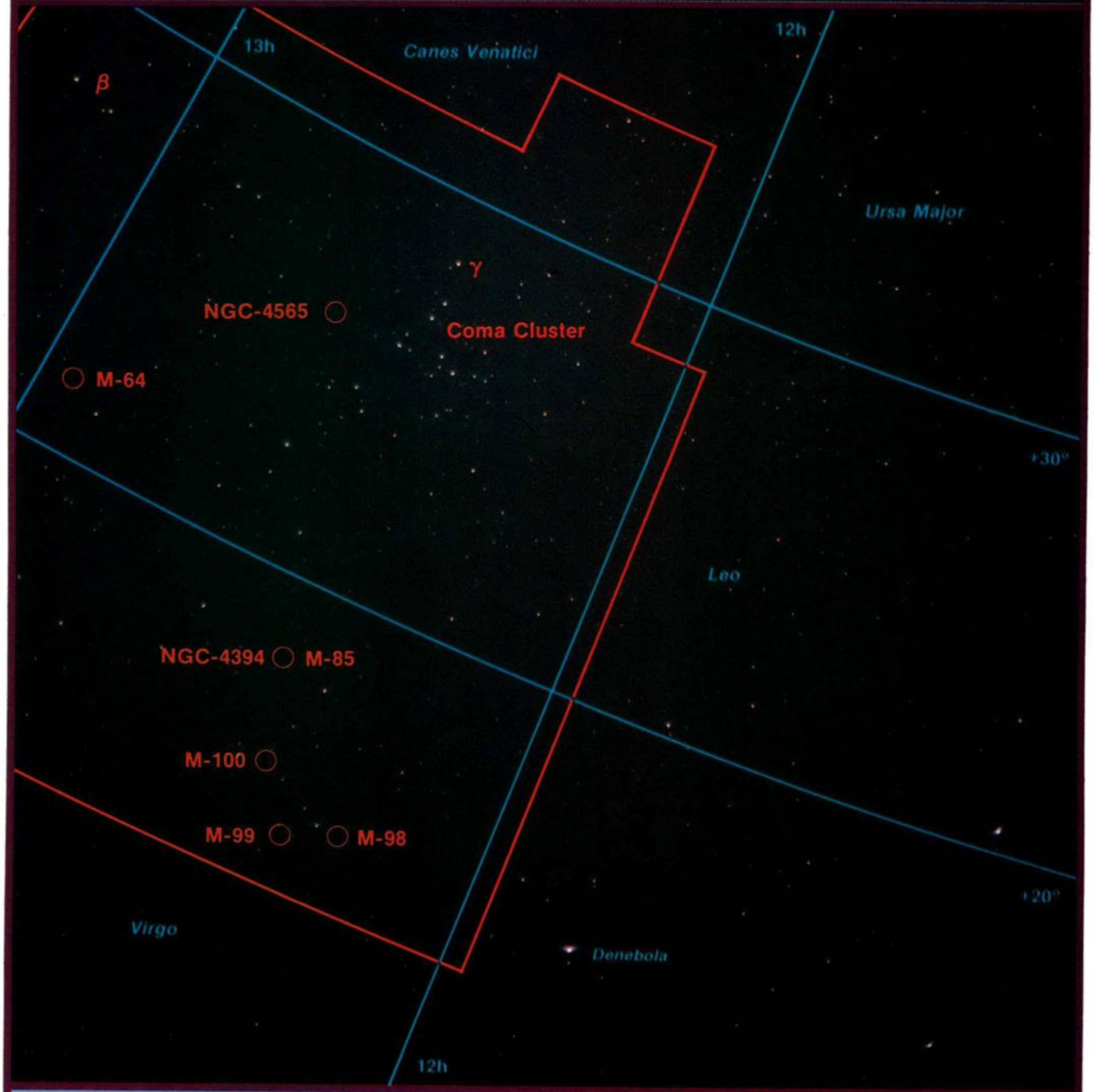
The last member of this galactic triad centered around 6 Comae is **M-100** — the largest spiral in the Coma-Virgo group. In small telescopes, M-100 looks like a round glow of magnitude 10.5 about 5 minutes in diameter. It is an Sc-type system with many secondary arms and a great deal of dust scattered throughout the galaxy all the way into the nucleus. Bright regions dot the spiral arms indicating a large amount of nebulous material. The total luminosity is close to 20 billion times that of the Sun, and the computed mass equals 160 billion Suns, making it comparable in size and brightness to the Great Andromeda galaxy.

The last object featured this month is **NGC-4565** — a real treat because it is so different from the others we observed. This galaxy is located 1.7 degrees east of **17 Comae** and is easy to find. It is also only 3 degrees from the North Galactic Pole. For small telescopes it is the best edge-on to observe — a small streak or shaft of fuzz. In a 10-inch, try to pick out the full extent of the arms. Down the center is a dark line, reminding us of the dust lanes and arms of our own Milky Way. Perhaps there is some observer on another planet in another galaxy who has the same view of us — a bulging central hub, flanked by ribbons of light, and bisected by dark galactic dust — the stuff life is formed from.

photo by Jack Marling

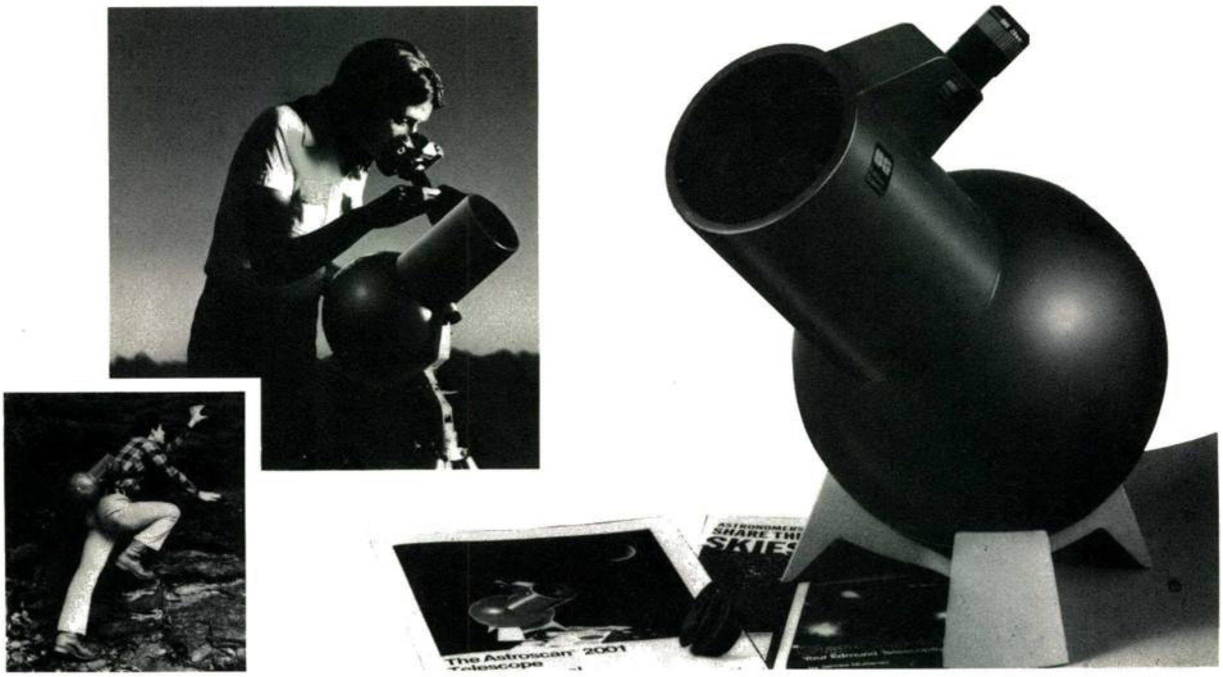
coma berenices

map by Robert Burnham


13h
Canes Venatici
12h
β
Ursa Major
γ
NGC-4565
Coma Cluster
M-64
+30°
Leo
NGC-4394
M-85
M-100
M-99
M-98
+20°
Virgo
Denebola
12h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (2000)	Dec.
M-98	§S	10.7	8′x2′	12h11m	+15°11′	12h14m	+14°54′
M-99	§S	10.1	5′x4′	12h16m	+14°42′	12h19m	+14°25′
M-100	§S	10.6	5′x5′	12h20m	+16°06′	12h23m	+15°49′
Coma Cluster	○	3.2	5°	12h22m	+26°00′	12h25m	+25°43′
M-85	§0	9.3	3′x2′	12h23m	+18°28′	12h25m	+18°11′
NGC-4394	§ʃ	11.7	2′x2′	12h23m	+18°29′	12h26m	+18°12′
NGC-4565	§S	9.6	15′x1′	12h34m	+26°16′	12h36m	+25°59′
M-64	§S	6.6	7′x3′	12h54m	+21°57′	12h57m	+21°41′
Alpha (α)	$\star^2$	5.1,5.1	0.3″	13h08m	+17°48′	13h10m	+17°32′
M-53	●	7.7	14′	13h11m	+18°26′	13h13m	+18°10′
NGC-5053	●	10.0	8′	13h14m	+17°57′	13h16m	+17°41′

★	*Star*
$\star^2$	*Double Star*
$\star^3$	*Triple Star*
m★	*Regular Variable*
∩★	*Irregular Variable*
Ӿ★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*



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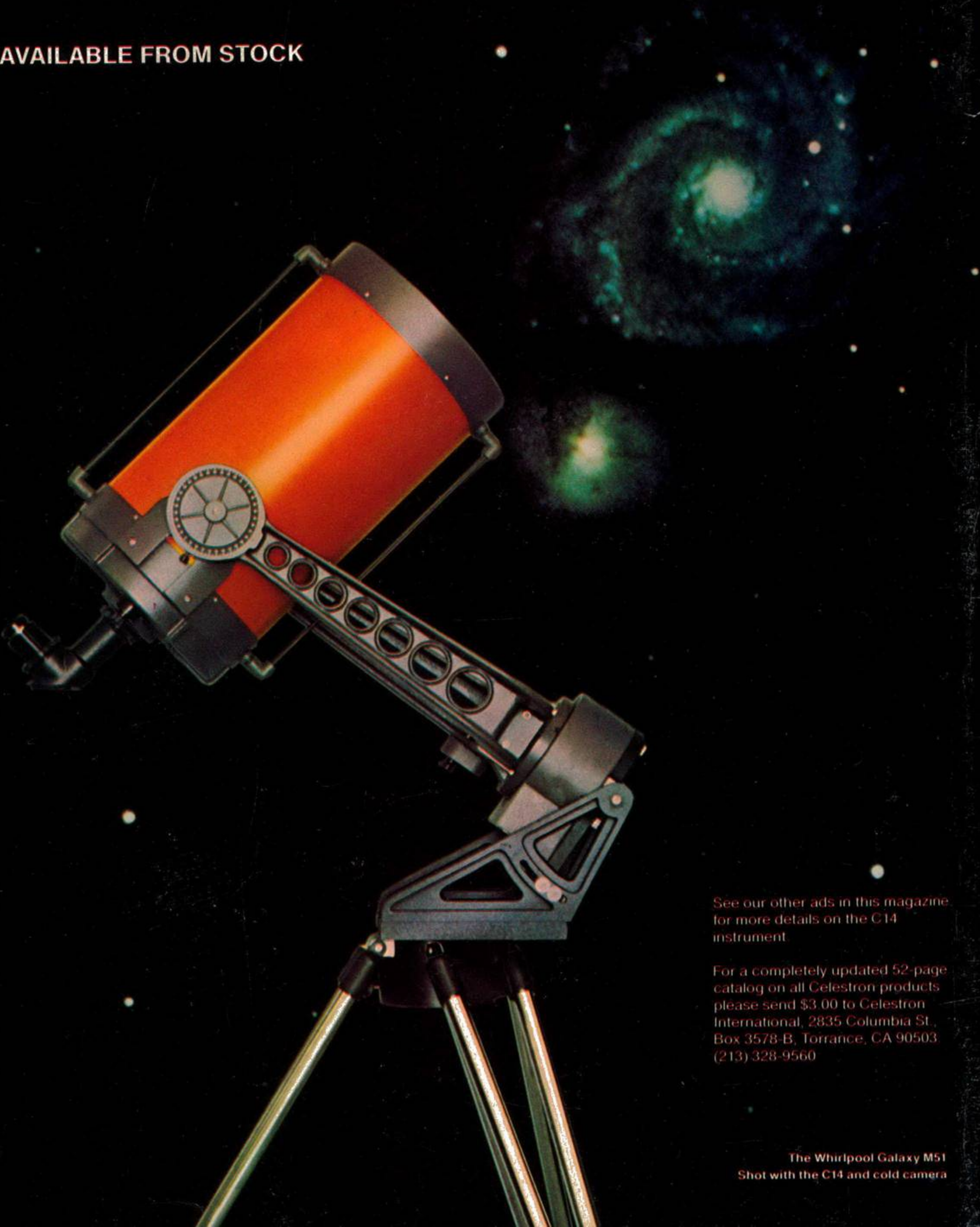

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